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LUHDORFF & SCALMANINI
Consulting Engineers

Final Report
Sealing of Base Wells

McClellan Air Force Base, California

February, 1984

LUHDORFF & SCALMANINI
Consulting Engineers

Eugene E. Luhdorff, Jr., P.E.
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312 Walnut Street
Woodland, CA 95695
(916) 661-0109

15 February 1984
LSCE File 83-2-019

Mr. Fred May
Contracting Officer
SM-ALC/PMKFE
Base Procurement
McClellan AFB, CA 95652

SUBJECT: Final Report
Contract F04699-83-C0666

Dear Mr. May:

Enclosed is the Luhdorff and Scalmanini, Consulting Engineers (LSCE) Final Report entitled "Sealing of Base Wells, McClellan Air Force Base, California."

The report incorporates the suggested comments offered during review of our Preliminary Report of 22 December 1983. It presents a review of previous groundwater investigations including the Phase II - Confirmation Study, an analysis of the construction of Base production and monitoring wells, alternative well sealing methodology, and recommendations for the sealing of base wells.

LSCE has recommended that a preliminary site investigation be conducted to evaluate each production well site prior to implementing a well sealing program. The requirements for such an investigation are contained in the report.

We are pleased to be able to provide our services to the Air Force. If you have any questions regarding this report please advise.

Sincerely,

LUHDORFF & SCALMANINI
CONSULTING ENGINEERS

Eugene E. Luhdorff, Jr.
Partner/Project Manager

Enclosure

FINAL REPORT

SEALING OF BASE WELLS
McCLELLAN AIR FORCE BASE, CALIFORNIA

Prepared for

U.S. AIR FORCE

SACRAMENTO ALC/PMKS

McCLELLAN AIR FORCE BASE, CALIFORNIA

February 1984

Prepared by

Luhdorff and Scalmanini
Consulting Engineers
Woodland, California

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EXECUTIVE SUMMARY

Introduction

Luhdorff and Scalmanini, Consulting Engineers (LSCE) was retained on September 23, 1983 by the United States Air Force, Sacramento ALC/PMKS, to prepare a Base Well Sealing Report for McClellan Air Force Base under Contract No. F04699-83-C0666. This report was to develop recommendations for sealing the gravel envelopes of Base production and monitoring wells to prevent the vertical movement of contaminants from the shallow groundwater aquifers to the deeper aquifers underlying the Base. The scope of work was to include the review and analysis of all researched data including well logs, maintenance records and schedules of all Base wells. Additionally, LSCE was to review and analyze data, conclusions and recommendations of the Installation Restoration Program, Phase II Confirmation for McClellan Air Force Base, prepared by Engineering Science.

Previous Work

McClellan Air Force Base, located near Sacramento, California, discovered volatile organic compounds (VOC) in its groundwater supplies in 1979. Of principal concern was the presence of trichloroethylene (TCE). Extensive investigations were conducted on the Base initially by McClellan's Environmental Protection Committee and later through the implementation of the Department of Defense Installation Restoration Program (IRP). Two phases of the IRP program have been completed. Phase I - Installation Assessment, conducted by the engineering firm CH2M Hill, identified potential areas for the migration of toxic and hazardous materials off the installation boundaries. Phase II - Confirmation

Study, conducted by Engineering Science (ES), consisted of a comprehensive preliminary environmental survey to define and quantify the presence or absence of contamination that might adversely affect public health or the environment. As a part of the latter investigation, ES implemented a monitoring program to determine the extent of organic constituents in groundwater. ES concluded that past disposal practices at McClellan have resulted in contaminating portions of the groundwater supplies underlying the facility but that the groundwater affected appeared to be limited primarily to the shallow aquifers. ES further concluded that the gravel envelopes of the Base production wells and certain monitoring wells are serving as conduits for the transfer of contaminated water from the shallow to the deep aquifers and as such, they should be sealed.

Findings

The findings developed from the LSCE study are presented in four principal chapters in this report: Chapter 2 - McClellan Groundwater Development; Chapter 3 - Sealing of Base Wells; Chapter 4 - Base Well Maintenance; and Chapter 5 - Recommendations.

Chapter 2 summarizes the groundwater hydrogeology underlying the Base, reviews the ES groundwater testing procedures and the conclusions reached by ES as a result of those tests, reviews all Base well and monitoring well construction data, and details the known construction features of each well.

In this chapter, LSCE questions the efficiency of the monitoring wells installed during the Phase II Confirmation Study and suggests, through a comparison of pumping rates obtained from the monitoring wells and one off-Base

(Higgs) well, a shallow well abandoned in 1979 due to TCE contamination, that aquifer characteristics developed in the Phase II study for the shallow aquifers may possibly be in error.

Review of the available well logs on the Base and three existing geophysical logs did not support the generalized concepts presented in the Phase II study that the shallow aquifers are totally separated from the deeper aquifers underlying McClellan, but rather, that the shallow aquifers are discontinuous and, as such, provide flow paths for potential migration of the known contaminants to the lower aquifers. Chapter 2 concludes with a listing of each production well's construction details.

Chapter 3 summarizes the methodology of well sealing and cementing. It reviews applicable techniques and presents the selected procedures recommended for Base well sealing. To perform proper sealing, LSCE proposes that a preliminary engineering site investigation be conducted which would include test drilling and installation of piezometer wells to develop needed lithology, geophysical logging, piezometric heads, and water quality determinations of selected aquifers at each production well site. The chapter addresses the fact that many of the wells at McClellan were constructed using direct mud rotary drilling equipment and that the gravel envelopes may now be already sealed by the bentonite muds used in construction which were rarely removed during early development. The data developed, combined with a pumping test of the production well, would determine if a requirement for sealing exists. It is believed that such an investigation could reduce the number of wells that would have to be sealed while providing the information necessary to effectively seal those wells requiring sealing. Additionally, the program would allow for continued

monitoring of all production wells in the future.

Chapter 4 reviews the maintenance activities for Base production wells at McClellan. It provides a detailed listing of past repairs or equipment changes for each production well and a summary of its water production, including static and pumping water levels for the past twenty years. Recommendations are made to include well performance characteristics as part of the routine data reported by Base personnel.

Chapter 5 sets forth the recommendations of LSCE for well sealing as developed by this study. They include:

1. that a preliminary engineering site investigation, as delineated in Chapter 3, be performed at Base production wells 1, 2, 12, 18, and 29, which are presently out of service due to the presence of TCE or excessive sand production; at wells 8, 10, and 13, which are currently operational and in service; and at wells 4, 11, and 20, which are operational but on standby.

2. that wells determined to require sealing, based upon fluid communication down their gravel envelope, be sealed using the secondary remedial cementing procedure known as the Bradenhead squeeze cementing method.

3. that upon completion of the seal installation, the well be pumped to determine the effectiveness of the seal placement.

4. that rehabilitation of selected monitoring wells on Base be performed; upon completion of the rehabilitation if the wells are found to be more efficient, that additional pumping tests be conducted to re-evaluate the aquifer characteristics developed during the Phase II Confirmation Study.

CHAPTER 1

INTRODUCTION

CHAPTER 1

INTRODUCTION

McClellan Air Force Base, which is located immediately north of the heavily populated City of Sacramento and its surrounding suburbs in Northern California, has discovered the presence of volatile organic compounds (VOC) in its groundwater supplies. Of principal concern is the presence of trichloroethylene (TCE) which has been found in some base supply wells in concentrations which exceed the maximum allowed by the United States Environmental Protection Agency and the California Department of Health Services. As such, the contaminated water has been classified as being hazardous to public health. The concern for the continued safe use of non-contaminated wells, as well as potentially restoring to use the contaminated wells, has focused attention on the need to examine the construction details of all base production and monitoring wells and to modify such wells as required to protect the local groundwater resources of the area.

This report evaluates the known construction details of all base production and monitoring wells which have been constructed at McClellan AFB and establishes recommended procedures to effect their sealing, monitoring or abandonment. The recommended sealing procedure has been developed to prevent the vertical migration of TCE and other identified hazardous constituents within the existing well's structure, from the suspected contaminated shallow aquifers to the deeper aquifers being utilized as the principal source of developed groundwater

throughout the Base, from occuring.

Additionally, this report reviews the Base Well maintenance practices and the conclusions and recommendations presented in the Phase II Confirmation Study by Engineering Science. As a result of this review, the report offers recommendations for additional testing and evaluation.

BACKGROUND

To effectively evaluate the Base production and monitoring wells, a thorough understanding of the contaminant problems experienced at McClellan AFB and the previous work that has been done to identify and classify its extent must be known. Such a review was accomplished as the initial task associated with this study. Because such reviews have been previously addressed in numerous reports which are identified herein, a restatement of the studies in depth in this report would be redundant. Luhdorff and Scalmanini, Consulting Engineers (LSCE) of Woodland, California, who have developed this report, will however, throughout its contents, offer comments on the methodology used and findings presented in the previous studies, particularly where such work and findings are believed questionable or methods used inappropriate. Such comments are provided not to discredit the work of others, but rather to qualify the methodology of the work proposed herein in order to protect the groundwater resources of the area.

PREVIOUS WORK

1. Base Activities

Concern for the quality of groundwater and the protection of this resource has focused the attention of this nation in recent years to the expanding number of discoveries of contaminated groundwater bodies nationwide. Such attention prompted the McClellan Environmental Protection Committee to voluntarily create a Groundwater Contamination Committee in August 1979 to determine if the McClellan community had a groundwater contamination problem. Their action was taken because of a VOC contamination problem which had been discovered in the Rancho Cordova area of Sacramento, an area near, but unrelated to the Base. The initial action of the committee was to analyze water from four strategically located base wells at each corner of the base. Prior to receiving the results of the initial well sampling, McClellan was contacted by the staff of the California Central Valley Regional Water Quality Control Board (CVRWQCB) to conduct groundwater monitoring for VOC, specifically TCE.

The results of initial sampling indicated low levels of TCE were present in one of the wells tested. Meeting with representatives of CVRWQCB, the City, the County and the California Department of Health Services (DOHS), a program of additional well sampling, both on and off the base, was agreed to, to determine the magnitude of the problem.

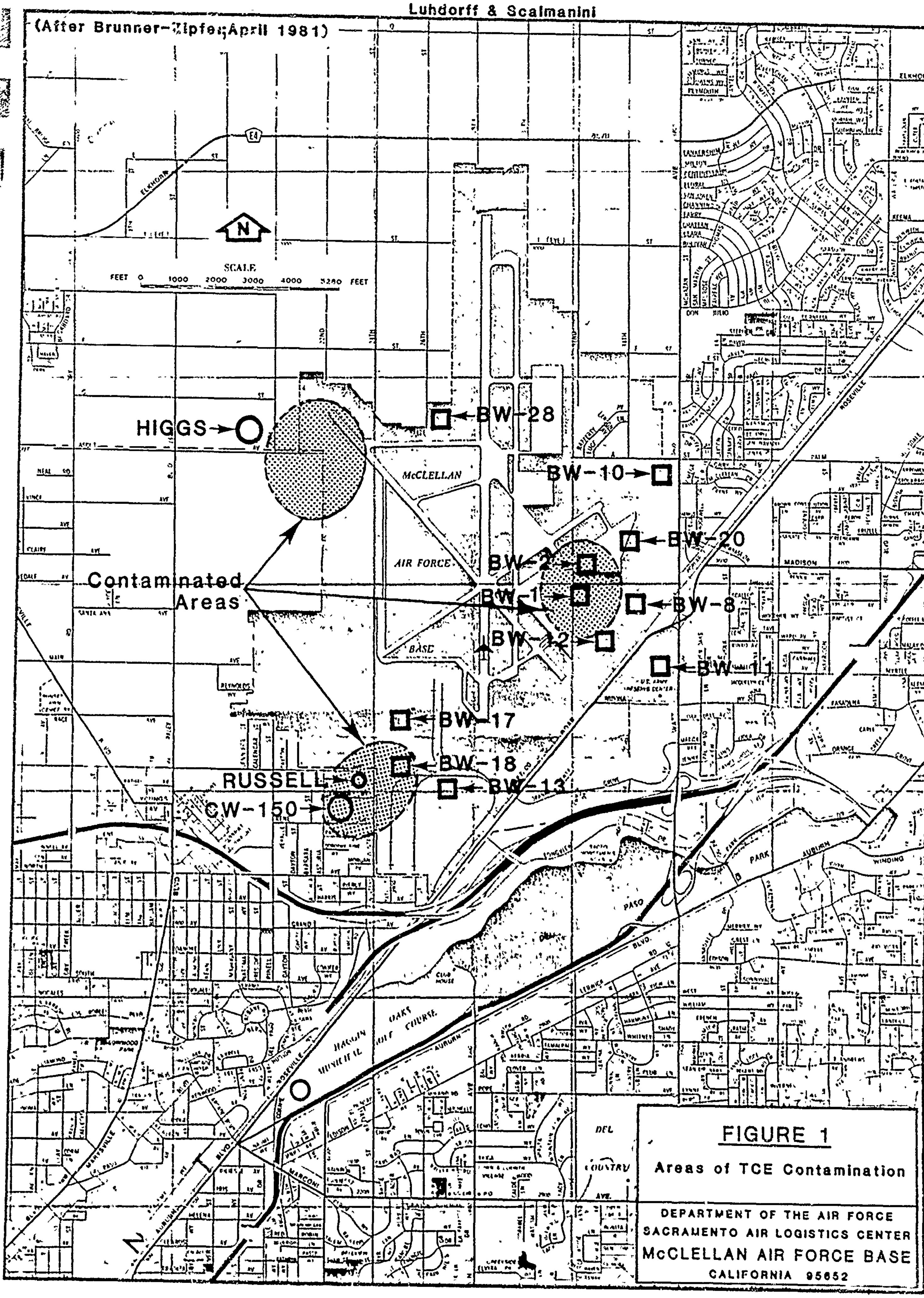
Throughout November 1979, on and off Base sampling resulted in identification of three areas of TCE contamination (Figure 1). As a result of the initial sampling, three off Base and two McClellan wells (No. 1 and 2) were shut down due to VOC contamination. Two of the three off Base wells were private household wells (Higgs and Russell) and the third belonged to the City of Sacramento (well no. 150). A third McClellan well (well no. 18) was found to contain TCE concentrations exceeding 4.5 ppb, but was left in service because

water from this well could be blended within the distribution system to levels which met the accepted State standards.

The presence of the VOC in the groundwaters under and adjacent to the Base was of significance to the greater Sacramento area. Until approximately 1979, it was not general practice in the United States for potable water to be sampled and analyzed for VOC contamination. Consequently, there was no prior history of the problem. National research organizations have done cancer risk studies to determine acceptable safe levels for human consumption with varying degrees of results. As an illustration of this point, the California Department of Health Services (DOHS) established 4.5 parts per billion (ppb) as a safe drinking water level whereas the USAF uses 270 ppb as an acceptable limit. McClellan AFB voluntarily chose to meet the recommended State standard of 4.5 ppb.

Once McClellan AFB learned that wells were contaminated with VOC, it initiated a still ongoing comprehensive program aimed at maintaining drinking water quality, source identification, and eventually, its removal. Based upon the initial water quality data, four geographical areas on the Base were identified as areas A, B, C, and D (Figure 2), and designated for further investigation. Area A was where Base wells 1 and 2 were located and taken out of service. Area B was where Base well 18 and nearby community wells were found to have low levels of contamination. Area C was where extensive past disposal sites and present landfill sites are located. Area D covers the past sludge pit sites used by the Base and was close to the earlier contaminated off-base area.

In order to more fully understand the composition of the groundwater aquifers underlying the Base, the committee performed a preliminary study of the


Luhdorff & Scalmanini
(After Brunner-Zipfel, April 1981)
SCALE
FEET 0 1000 2000 3000 4000 5280 FEET
HIGGS
BW-28
McCLELLAN
AIR FORCE
BASE
BW-10
BW-20
BW-2
BW-1
BW-8
BW-12
BW-11
Contaminated Areas
BW-17
BW-18
RUSSELL
BW-13
CW-150
HAGGIN MUNICIPAL OAKS GOLF COURSE
DEL PASO COUNTRY
FIGURE 1
Areas of TCE Contamination
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McCLELLAN AIR FORCE BASE
CALIFORNIA 95652

geologic and groundwater characteristics in the McClellan area. This study comprised Appendix 4 of the "Final Report for Investigating Groundwater Contamination as of 30 April 1981." The report, which was prepared by Paul G. Brunner and Jacqueline Zipfell, reflected the composite effort of the 2852 Civil Engineering Squadron's Operational and Design Groups, Bioenvironmental Engineering Services, and Legal Staff of the Base.

The report detailed the work that had been accomplished on the Base to identify the locations where TCE had been found, the results of water quality testing, and the intended scope of work that was to be performed in the future in order to protect the quality of groundwater underlying the facility.

The initial research of past Base disposal practices of VOC's and other potential contaminants caused the Base Committee to realize that a total Base monitoring system needed to be constructed to determine the extent of the contaminant problem in order to protect the Base and off-base groundwater supplies. McClellan initially programmed four wells to be constructed (Figure 3). Construction details of these wells are shown on Figure 4. Monitoring wells 1 and 2 were located adjacent to the Base's most recent sludge pit and landfill. Monitoring well number 3 was located near McClellan's hazardous material storage facility and monitoring well number 4 was located on the east side of the Base to monitor in-coming water flows. The latter well site was selected based upon CVRWQCB's provided data that described the local groundwater flow as being from northeast to southwest.

Tests conducted in January 1980 showed only low levels of TCE in production well number 1 and the unit was placed back in service. By March, contamination

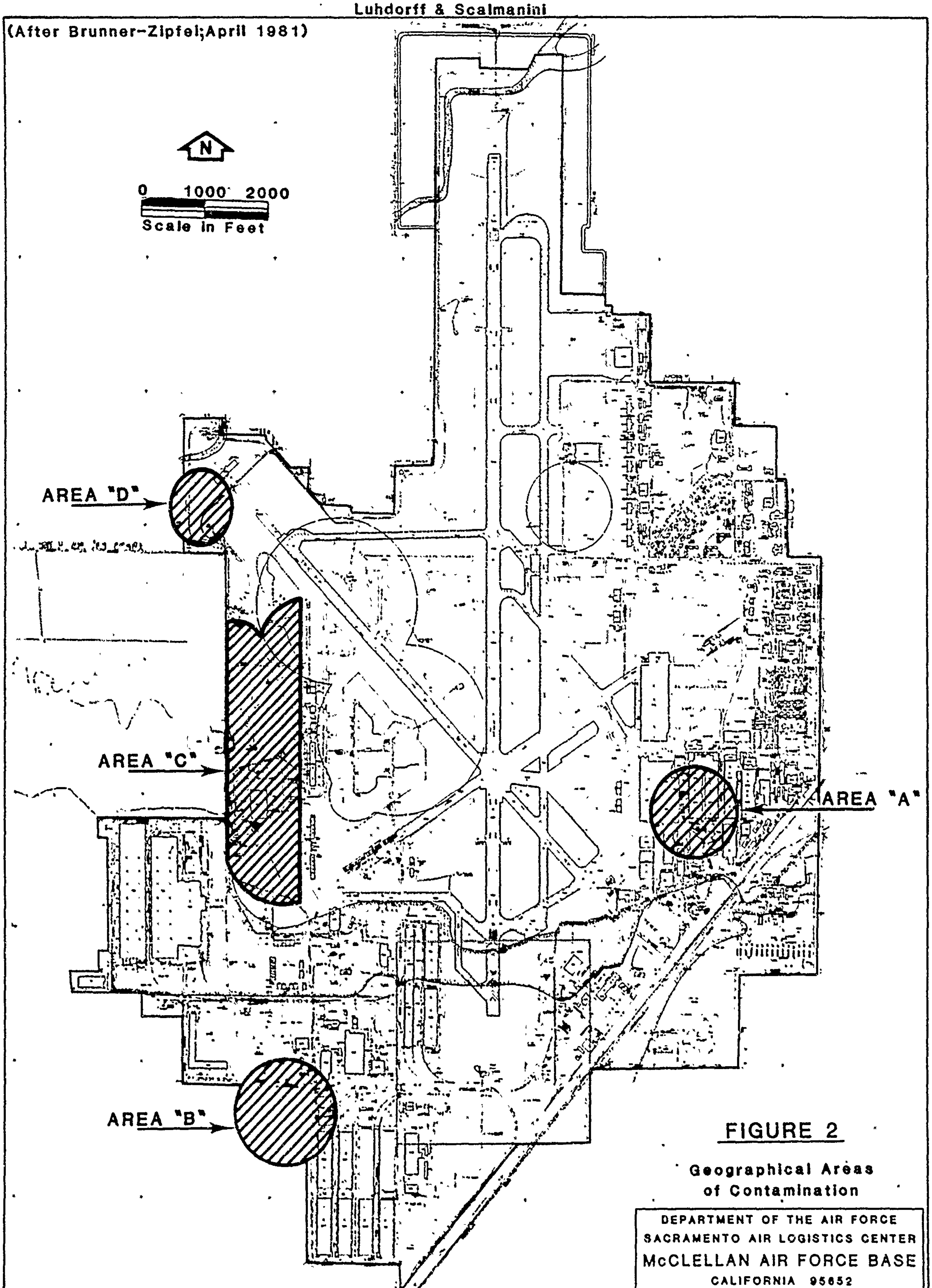

FIGURE 2

Geographical Areas of Contamination

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levels began to increase and well number 1 was again taken out of service. Base testing of the well on two separate dates for periods of pumping of up to eight hours showed erratic levels of TCE concentrations. The results of these tests are contained in the McClellan report previously referenced.

In April 1980, construction of the initial four monitoring wells was commenced. Wells number 1, 2, and 4 were completed to depths of 249 feet and well number 3 to a depth of 205 feet. Each was gravel packed and contained vertical milled slot perforations from 75 feet (wells 1 and 2), 80 feet (well 3) and 85 feet (well 4) to the bottom of the respective wells.

Samples of the water from each of the monitoring wells were taken weekly following construction. Wells 1 and 2 consistently were found to contain TCE, with well number 1 exceeding the acceptable concentrations throughout the reported period from June through August. Well number 2 exceeded the acceptable limits for TCE on three of the weekly reports. Wells 3 and 4 remained continually free of VOC contamination.

In August of 1980, production well number 12 was taken out of service when TCE concentrations were found to be 35 ppb.

In order to determine which of the numerous aquifers contained the TCE contaminants found in monitoring wells 1 and 2, the Base in September 1980 conducted selective aquifer sampling within the cased monitoring wells. The results of these tests indicated that the highest concentrations were found to be near the water surface or static levels of the wells. Table 1 and 2 present the findings from the investigation.

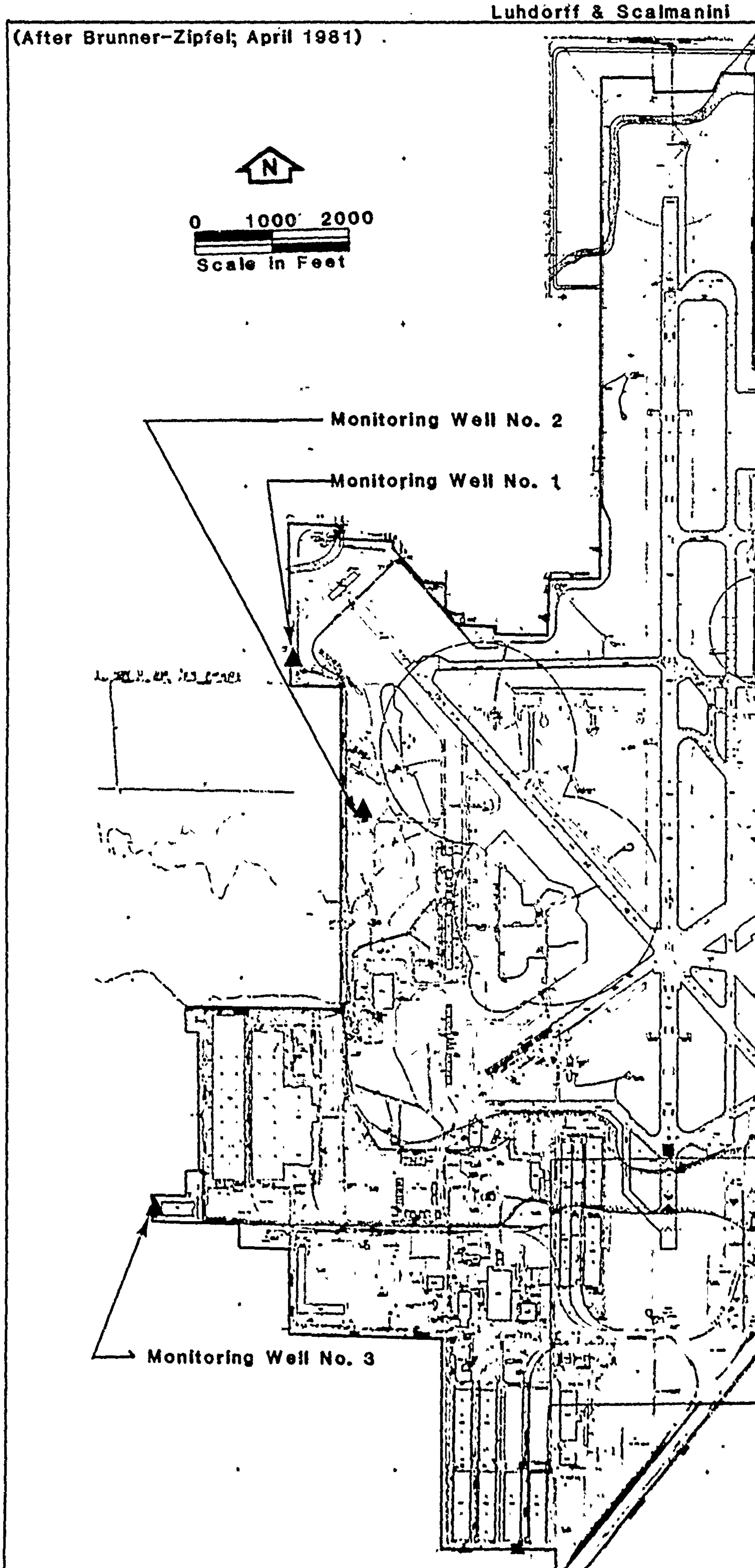

FIGURE 3

Location Map of
Monitoring Wells 1, 2, 3, and 4

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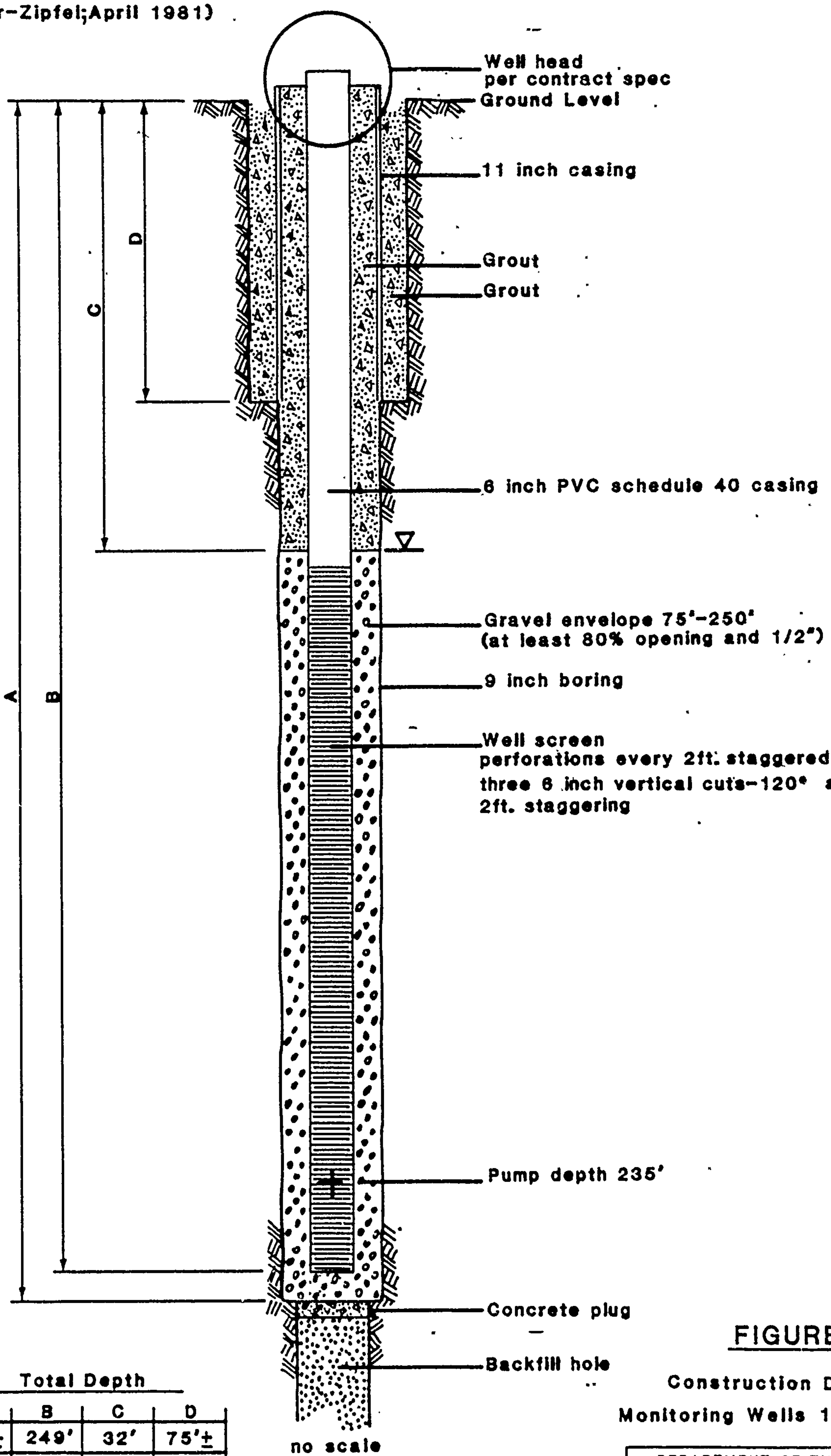
CALIFORNIA 95652

(After Brunner-Zipfel;April 1981)



Total Depth

Well	A	B	C	D
1	250'±	249'	32'	75'±
2	250'±	249'	32'	75'±
3	206'±	205'	8'	80'
4	250'±	249'	8'	85'

FIGURE 4.

Construction Details of Monitoring Wells 1, 2, 3, and 4

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CALIFORNIA 95652

TABLE 1

Monitoring Well No. 1
Volatile Organics (ppb)

Contaminant/Approx. Depth Sample Taken	Water Surface 79'	115'	148'	205'	220'
1,1 - Dichloroethylene	5,600	852	5.3	2.3	54.0
1,1 - Dichloroethylene	350	36	0.33	0.18	4.4
1,2 - Dichloroethylene	500	110	0.41	0.17	4.5
1,1,1 - Trichloroethane	12,000	1,066	1.55	0.62	6.8
Trichloroethylene	9,100	1,008	7.0	3.4	73.6
1,2 - Dibromoethane					5.9
Dibromochloromethane					51.0
DETECTION LIMIT	100ppb	200ppb	0.5ppb	0.5ppb	10ppb

COMPOUNDS WERE DETECTED BY THE PURGE/TRAP TECHNIQUE WITH COULSON GAS CHROMATOGRAPHY.

Monitoring Well 1
Priority Pollutants Found (ppb)

Contaminant/Depth Sample Taken	79'	Water Surface 148'	205'	220'
1,2 - Dichlorobenzene	126	None Detected (ND)	ND	ND
1.3 - Dichlorobenzene	12	ND	ND	ND
Bis (2-Ethylhexyl) Phthalate	10	10	10	10

TABLE 2

Monitoring Well No. 2
Volatile Organics (ppb)

Contaminant/Approx. Depth Sample Taken	Water Surface 81'	113'	145'	170'	208'
1,1 - Dichloroethylene	7.8				
1,1 - Dichloroethane		1.4	0.90	1.2	
Chloroform*					
1,1,2 - Trichloro-2,2,1-Trifluoroethane*		1.8			
1,2 - Dichloroethane	2.4	0.70	0.58	0.48	
Trichloroethyene	19	9.2	4.6	5.3	1.4
1,1,2 - Trichloroethane*		1.1	0.68	0.73	
Dibromochloromethane*					
Trans-1,2 - Dichloroethylene			0.61		
DETECTION LIMIT	0.5ppb	0.5ppb	0.5ppb	0.5ppb	0.5ppb

COMPOUNDS WERE DETECTED BY THE PURGE/TRAP TECHNIQUE WITH COULSON GAS CHROMATOGRAPHY.

*Pairs cannot be distinguished by the above technique.

Monitoring Well 2
Priority Pollutants Found (ppb)

Contaminant/Depth Sample Taken	Water Surface 81'	113'	208'
Bis (2-Ethylhexyl) Phthalate	15	10	13

In the Fall of 1980, McClellan initiated an expanded program to find the source of contamination in Areas A and B. In Area A, five soil boring were made near well number 1 using a hollow stem auger rig to depths up to 120 feet. Soil samples were analyzed from each boring. Only one sample contained TCE. Two borings were completed into monitoring wells (B6 and B9); however, no water samples were collected for analysis. In area B, four sites were selected and borings made from 120 to 140 feet. Three of these borings were completed into monitoring wells (B1, B3, and B4). Water samples were not collected from the wells. The five completed monitoring wells (designated MW-5 thru MW-9) were cased with 4 inch PVC casing in 6 inch augered holes and were perforated from 20 feet beneath the surface to the bottom of the well.

In February 1981, in order to prevent the downward migration of contaminants, monitoring wells MW-1 and MW-2 were filled with a mixture of cement grout and bentonite clay. Well MW-1 was accidentally filled completely and is no longer available for use. Well MW-2 was sealed back to a depth of 120 feet.

In February 1981, Base personnel met with representatives of the consulting firm CH2M Hill to implement Phase I of a program designed to discover and restore all past disposal sites. While the program was not intended to be the prime program used by McClellan to resolve the VOC contamination problem, the results of the study have been valuable in broadening the understanding of the origin of the contaminants.

Since the McClellan report was published in April 1981, Base personnel have continued monitoring the Base wells and have provided necessary records and field

data for the private consultants retained by the Air Force as part of the ongoing review and assessment of the contaminant problem.

Phase I - Installation Assessment (CH2M Hill)

The identification of hazardous waste disposal sites at military installations was directed by the Defense Environmental Quality Policy Memorandum 80-6 of June 1980 and implemented by the Air Force in December 1980 as a positive action to insure compliance of military installations with the Resource Conservation and Recovery Act (RCRA) and implementing regulations. Phase I of the Department of Defense Installation Restoration Program, performed by CH2M Hill, was a record search program to determine the potential, if any, for migration of toxic and hazardous materials off the installation boundaries. The Phase I study was completed in July 1981 at McClellan.

The report of CH2M Hill, which included information generated by the Air Force (Brunner and Zipfell, 1981), identified two main areas of concern: (1) organic solvents found to be present in the groundwater and (2) polychlorinated biphenyls (PCB's) contained in the soil in a small area located in the northwest corner of the base.

Forty-six active and inactive waste disposal and storage sites were identified. Recommendations were presented in the Phase I report for expanded groundwater monitoring which would be carried out in the Phase II study to be performed by the engineering firm of Engineering Science.

The Executive Summary of the Phase I study is contained in Appendix A.

Phase II - Confirmation (Engineering Science)

The confirmation study, performed by Engineering Science and reported by them in June 1983, was to determine the extent and magnitude of groundwater contamination resulting from previous waste disposal practices at McClellan; to develop environmental conditions resulting from past waste disposal activities; and to recommend measures to mitigate impacts for identified contaminated areas.

Forty-eight monitoring wells were constructed during the study to identify the location of contaminants, to determine aquifer characteristics, and ultimately to determine or propose methodology to protect and restore the quality of the groundwater underlying McClellan.

The Executive Summary and proposed recommendations by Engineering Science are contained in Appendix B. Of significance to this investigation and report is their recommendation to seal the gravel packs on wells 1, 8, 13, 18, 20, and 29, to abandon base well number 2 and to seal the gravel packs in monitoring wells 1 through 4.

Among the findings presented in the Confirmation Study were:

1) That the VOC contaminants were found at the locations previously identified as Areas A, B, C, and D.

2) That the groundwater containing the VOC's was principally the shallow aquifers located 80 to 100 beneath the surface.

Based upon one low capacity pumping test and recovery study, and the results of two slug injection tests in each of three monitoring wells, the identified aquifer system was classified as being of low permeability and consequently having low transmissivity. The deeper aquifers, those principally being used for potable water supplies at McClellan, were in general found to be absent of EPA priority pollutants. The need to seal the gravel packs of the existing Base wells was recommended to prevent the vertical migration of groundwater from the contaminated shallow aquifer system through the pack and into the deeper aquifer system.

Specific comments by LSCE concerning the findings presented in the Phase II report are incorporated throughout this report.

Scope of Work

The services of Luhdorff and Scalmanini, Consulting Engineers (LSCE) of Woodland, California, in conjunction with McClellan Air Force Base Contract No. F04699-83-C0666 dated 23 September 1983, entitled "Sealing of Base Wells" is divided into two separate phases of work: Phase I, the development of a seal base well report; and Phase 2, the development of construction documents to implement the findings and recommendations of Phase 1.

The work presented herein completes the tasks assigned LSCE in Phase 1 - Development of Base Wells Sealing Report. It has included the following:

1. A survey of the McClellan well sites to determine appropriate well

sealing methods and wells requiring sealing. In the assigned scope of work McClellan officials summarized the existing well information regarding known conditions and other requirements as follows:

a. Base Production Wells 1, 8, 13, 18, 20, and 29 (with well logs), and Wells 10, 11, 12, and 13 (no known well logs).

b. Base Production Wells 2 and 7 (abandoned).

c. Monitoring Wells 1, 2, 3, and 4 are known to require sealing.

d. Other wells determined to require sealing from review of data and surveys.

2. A review and analysis of all available data including well logs, maintenance records, and schedules of all base wells. The review and analysis of data was to include the conclusions and recommendations of the Installation Restoration Program, Phase II Confirmation for McClellan AFB, prepared by Engineering Science.

3. Development of specific methods for sealing base wells as recommended by LSCE and approved by the Government. The methods selected were to depend on the type of well construction at each site, site situations, maintenance activities, and other data gathered. Recommendations for not sealing wells were to be presented where appropriate. The method of sealing chosen was to consider the latest water well standards for California and other proven technology for wells.

To accomplish these tasks, the LSCE work program has included:

1. Inspection of McClellan well sites and pumping stations.

2. Review of previous studies conducted for the Base, including:

a) "Final Report for Investigating Ground Water Contamination as of 30 April 1981" (Brunner and Zipfell - 1981).

b) Phase I - "Installation Assessment of the Installation Restoration Program - July 1981" (CH2M HILL).

c) Final Report - "Installation Restoration Program Phase II - Confirmation" July 1983 (Engineering Science).

3. Review of comments received by McClellan from various agencies concerning the Confirmation Study.

4. Review of well construction records - MAFB.

5. Review of maintenance records for wells and pumps - MAFB.

6. Analysis of sealing methodology applicable to MAFB wells.

7. Preparation of findings.

This report presents the results of the study, including the development of sealing methodology for the selected wells and recommendations for future action. Apart from this introductory section, the main report contains four chapters. Following are brief descriptions of each chapter.

<u>Groundwater Development - McClellan Air Force Base</u> - presents a brief review of the groundwater hydrogeology underlying the Base, a discussion of the contamination problems experienced, and a review of all Base production and monitoring wells.

Sealing of Base Wells - defines the problems associated with well sealing, reviews the methodology presented in the Confirmation Study for well sealing, lists the wells recommended for sealing, and details the methodology recommended to be used for the selected wells.

Base Well Maintenance - discusses the recommended action to be implemented in the operation of the Base wells prior to sealing, the recommended maintenance to be performed at the time of sealing, and sets forth recommendations for future monitoring of the Base production wells.

Recommendations - summarizes the findings reached during this study and presents a summary of the actions recommended to be taken in sealing of the existing base wells.

The appendices that follow these chapters contain specific data or summaries referenced in the report.

CHAPTER 2

GROUNDWATER DEVELOPMENT

McCLELLAN AIR FORCE BASE

CHAPTER 2

GROUNDWATER DEVELOPMENT

MCCLELLAN AIR FORCE BASE

Hydrogeology

Since its establishment in 1936, McClellan Air Force Base has developed its water resources from the groundwater underlying the facility. The discovery in 1979 that the groundwater had become contaminated with volatile organic compounds (VOC), specifically trichloroethylene (TCE), created the necessity to examine the geologic and hydrogeologic features of the aquifer systems being utilized by the Base. The necessity of knowing the lithology at each well site, the various aquifers encountered in each well, their aquifer characteristics, and potential for becoming contaminated in future years, is essential in the development of proper sealing requirements to protect each well and its associated groundwater source.

In the past forty seven years of base operations, McClellan has constructed 25 wells, of which 10 are permanently abandoned and 4 have been taken out of service due to concentrations of TCE exceeding acceptable limits for safe use.

The three previously referenced studies each contain a description of the local geology and describe the source of McClellan's groundwater. Brunner and Zipfell's Appendix 4 "Local Geology and Ground Water Study", which is included as

Appendix C of this report, describes three geologic formations (Victor, Fair Oaks and Mehrten) which underlie McClellan as "weaving and discontinuous ancient river and stream beds consisting of gravels, sands silts and clays of various densities. It is these past river beds that serve as the best groundwater aquifers. Wells at McClellan are designed to withdraw water from these older river beds in the Fair Oaks and Mehrten Formations."

Groundwater throughout Sacramento County has been developed principally from the Fair Oaks and Mehrten formations. Of the hundreds of wells constructed, many have been drilled using highly sophisticated sampling, logging and completion techniques to define specific aquifer characteristics, and to identify quantitative and qualitative properties. Countless attempts to correlate detailed well logs in the Sacramento area, one to another, have demonstrated the discontinuity of these formations in past hydrogeological investigations.

Engineering Science (ES) in their groundwater investigation concentrated their efforts on what they described as being the "shallow sands" which had been found to contain the highest concentrations of TCE. In the construction of 48 monitoring wells, 32 were completed at depths less than 120 feet. ES postulated that a shallow water bearing sand formation ranging in thickness from 1 to 17 feet and located 80 to 100 feet beneath the ground surface was the suspected aquifer that allowed the contaminants to move downgradient in response to the regional hydraulic gradient characterized as being from the northeast to the southwest. ES additionally described the formations underlying the shallow aquifer as being "disconnected from the shallow aquifer and separated by at least 20 feet of predominately fine-grained material."

Analysis of the monitoring well logs which are contained in the ES report does not support the broad generalization of the shallow aquifer system nor the separation of such a system from the deeper aquifers by predominately fine-grained materials. Examination of the majority of the logs which were prepared from direct rotary drill cutting returns during the monitoring well construction illustrates the discontinuity of the formations underlying the base. The acknowledgement by ES of their inability to provide a detailed geologic cross-section between the various monitoring well sites further demonstrates this discontinuity.

It would have been perhaps more reasonable to state that localized permeable formations do exist in a discontinuous pattern throughout the base, many of which overlie less permeable formations, allowing groundwater containing the TCE to move laterally in the more permeable environment in response to the aquifer's hydraulic gradient but that such groundwater would, in response to a vertical gradient, be able to continue its downward migration to the lower aquifers.

The rate of groundwater movement within an aquifer is a function of the aquifer's permeability and its existing hydraulic gradient. The ES report developed permeabilities for the shallow aquifers from the results of one low capacity (0.82 gpm) pump test and recovery study and two injection slug tests, conducted in three of the monitoring wells. The reported permeability ranged from 0.8 to 4.2 gallons per day per square foot. Based upon aquifer thickness, transmissivity was calculated to range from 4.7 to 21 gpd per foot. These values are important in establishing estimates of probable contaminant movement from any established source. The values presented in the ES report are highly questionable when one considers past water development practices in the area.

Groundwater development in the Sacramento Valley, and specifically in the vicinity of McClellan, commenced with the construction of shallow wells prior to the turn of the century. As the demand for water increased, wells were constructed deeper, first through the Victor formation, thence the Fair Oaks and finally into the older Mehrten sequence. Numerous wells still exist that produce water from the shallow Victor formation. The discovery of TCE in the Higgs well, a well which was measured by LSCE and found to be 115 feet in depth, is an excellent illustration of this point.

The Higgs well, which was found contaminated with TCE during the initial canvass of off-base wells in 1979, was an operating well producing water from the shallow aquifer system. LSCE made inquiries to establish the flow rates produced from the Higgs well for comparison to the low flow rates developed from the constructed monitoring wells. Records were available from the Sacramento Municipal Utility District (SMUD) for two pump efficiency tests. Test No. 1 was conducted in 1948. The static water level was measured at 27.1 feet. The pump capacity was 75 gallons per minute (gpm) with a drawdown of 4.4 feet. The resulting specific capacity was calculated to be 17 gpm/ft. of drawdown. Test No. 2 was conducted in 1952. The static level was then measured at 32.9 feet, pump capacity was 57 gpm, the drawdown 2.7 feet, which developed a specific capacity of 21.1 gpm/ft. drawdown.

In 1979, at the time of the discovery of the TCE, the Higgs well system was being used to support the water requirements of four households and was additionally used to supply water for limited sprinkler irrigation of the property. Based upon only the sprinklers in operation, the water produced from the well in 1979 was in excess of 20 gpm from a static water level of 75 feet.

The values obtained from the pumping tests are directly related to the aquifer's permeability and transmissivity. Using conservative estimates of the well's present minimum specific capacity, the transmissivity of the Higg's aquifer would be in the range of 8000 to more than 15000 gpd/ft. Permeability, assuming an aquifer thickness of 40 feet, again a highly conservative number, would be on the order of 275 to 375 gpd per square foot. These values are more consistent with expected values of permeability for fine sands than the calculated values of 0.8 to 4.2 gpd per square foot reported in the Confirmation Study. Table 3 presents the range of typical coefficients of permeability for various formations normally encountered in well construction. If the higher permeabilities do exist, and if a local hydraulic gradient of 3.7 feet per mile is present, as reported by ES, then the estimated velocity of the groundwater would be in excess of 600 ft./year as compared to the reported value of 8 feet per year.

TABLE 3

TYPICAL COEFFICIENTS OF PERMEABILITY

MATERIAL	PERMEABILITY (GPD per Sq. Ft. @ 60 degrees F.)
Granite	0.0000009 - 0.000005
Dolomite	0.00009 - 0.009
Limestone	0.00001 - 0.002
Basalt	0.00004 - 1
Sandstone	0.003 - 30
Beach Sand	100 - 400
Alluvium	(See individual materials below)
Clay	0.001 - 1

Very Fine Sand	10	- 100
Fine Sand	100	- 1,000
Medium Sand	1,000	- 4,500
Coarse Sand	4,500	- 6,500
Very Coarse Sand	6,500	- 8,000
Very Fine Gravel	8,000	- 11,000
Fine Gravel	11,000	- 16,000
Medium Gravel	16,000	- 22,000
Coarse Gravel	22,000	- 30,000
Very Coarse Gravel	30,000	- 40,000
Cobbles	Over 40,000	

A detailed analysis of the construction details of monitoring well 44, which was used for the pump test and recovery study during the Confirmation Study, is not possible from the data contained in the appendices of the ES report.

A review of the time sequence for the rig that drilled the well indicates that mobilization, drilling, casing, gravel packing and development all occurred within eight hours. It is questionable how efficiently the mud rotary drilled well could be completed and developed in this short time sequence. It would appear, based upon the fact that the aquifer system completed into is saturated and the fact that the Higgs well produced considerably more water, that a question must be raised regarding the hydraulic efficiency of the monitoring well. If inefficient, then aquifer characteristics based upon its performance as reported, would be questionable.

An analysis of the aquifer characteristics of the deeper aquifers was not presented in the Phase II confirmation report. These values are of importance in estimating the effect of deep well pumpage on the regional hydraulic gradients when the deeper wells have gravel packs intersecting the shallow aquifers in their completion.

Contaminant movement from the shallow aquifers down the gravel pack of

deeper wells can be induced by pumping of the production wells in response to the hydraulic gradient created. To define this impact, the deeper wells should be evaluated as will be addressed in Chapter 3 of this report.

In summary, the following hydrogeologic conditions appear to exist at McClellan.

1. Groundwater is present in three geologic formations:

   a. The Victor formation - to depths of 60 to 80 ft.

   b. The Fair Oaks formation - from depths below the Victor formation to total depths of 275 to 300 ft.

   c. The Mehrten formation - from depths below the Fair Oaks formation to depths of nearly 2000 feet.

2. Groundwater on the Base is principally developed from the Fair Oaks and Mehrten formations.

3. VOC contaminants have been found in the groundwater aquifers to depths of at least 80 to 100 feet below the ground surface.

4. Contaminated waters can move laterally within the sand and gravel aquifers in response to localized hydraulic gradients.

5. The shallow sand and gravel aquifers appear to be discontinuous and may intersect other sequences which will allow deeper penetration of the contaminants if a sufficient hydraulic gradient exists.

6. The gravel envelopes of all wells provide potential conduits for the downward migration of contaminants during pumping.

Base Production Wells

McClellan AFB historically established a consecutive numb._ing sequence for supply wells under its jurisdiction. As wells were constructed or acquired during land aquisition, they were assigned the next number in sequence. Twenty-nine wells have been assigned such numbers during the history of McClellan's operations. (Table 4).

Determining the present status of each numerically listed well required an extensive record search at McClellan from the files of the Engineering, Maintenance, and Real Estate sections and at the U.S. Army Corps of Engineer's office in Sacramento. The record research did not provide the locations of several wells which over the years were removed from service or abandoned. Currently, the following is known about each well.

-Four wells, numbers 5, 15, 25, and 26 were located off-base at remote McClellan facilities and are not within the local groundwater study area.

-Seven wells are known to be abandoned. They are numbers 3, 6, 7, 9, 16, 19, and 27.

-Four wells are thought to have been abandoned but their exact locations are not known. They are believed to be former irrigation wells located

TABLE 4

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
SUMMARY OF BASE WELLS

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

WELL NO.	DATE OF CONSTR.	DEPTH CASING (feet)	CASING DIA. (inches)	PERFORATION DEPTH (feet)	SEAL DEPTH (feet)	GRAVEL PACK DEPTH	STATUS/REMARKS
1	APRIL 1937	400	12	162-174 233-236 247-252 263-266 276-294 338-357 378-396	39	400	OUT OF SERVICE DUE TO CONTAMINATION
2	APRIL 1937	298	12	100-112 141-158 180-197 282-296	40	298	OUT OF SERVICE DUE TO CONTAMINATION
3	N/A	N/A	N/A	N/A	N/A	N/A	ABANDONED OR DESTROYED
4	JULY 1941	382	12	169-382	81	382	USED FOR IRRIGATION STANDBY ONLY
5							OFF-BASE; NOT A PART OF THIS STUDY
6	N/A	N/A	N/A	N/A	N/A	N/A	ABANDONED OR DESTROYED
7	JULY 1942	398	12	145-398	50	398	DESTROYED
8	JULY 1942	625	12	N/A	43	N/A	IN SERVICE
9	JULY 1953	N/A	14	N/A	N/A	N/A	ABANDONED OR DESTROYED
10	1945	400	14/12	170-392	N/A	400	IN SERVICE
11	1945	395	14/12	154-395	N/A	395	IN SERVICE - STANDBY
12	N/A	390	12	164-384	80	390	OUT OF SERVICE DUE TO CONTAMINATION
13	1945	391	14/12	178-391	N/A	391	IN SERVICE

TABLE 4 - Continued

McCLELLAN AIR FORCE BASE
SUMMARY OF BASE WELLS

14	N/A	N/A	N/A	N/A	N/A	N/A	NO INFORMATION AVAILABLE
15							OFF-BASE; NOT A PART OF THIS STUDY
16	N/A	N/A	N/A	N/A	N/A	N/A	ABANDONED OR DESTROYED
17	N/A	353	16	216-224 286-294 302-312	N/A	353	IN SERVICE
18	FEB. 1953	408	14	169-185 210-260 304-349 378-387	50	408	OUT OF SERVICE DUE TO CONTAMINATION
19	NOV. 1952	360	N/A	174-193 214-239 305-360	N/A	360	ABANDONED OR DESTROYED
20	1968	600	14	178-190 234-274 338-374 494-506 564-598	N/A	600	STANDBY SOURCE FOR BUILDING 200
21 THRU 24	N/A	N/A	N/A	N/A	N/A	N/A	ABANDONED OR DESTROYED
25							OFF-BASE; NOT A PART OF THIS STUDY
26							OFF-BASE; NOT A PART OF THIS STUDY
27	JUNE 1962	261	6	175-185 200-210 240-260	71	261	ABANDONED
28	1968	236	8	144-147 205-212 233-236	72	NONE	IN SERVICE
29	AUGUST 1981	575	16	251-555	53	604	OUT OF SERVICE DUE TO EXCESSIVE SAND PRODUCTION

N/A - Not Available

in the northeast section of the base. The wells are 21, 22, 23, and 24.

-The location or status of Well No. 14 is not known.

-The remaining wells have known locations and are classified as follows:

1. Wells out of service due to the presence of TCE:

   Wells 1, 2, 12, and 18.

2. Wells that are operational and in service:

   Wells 8, 10, 13, 17, and 28

3. Wells that are operational but on standby:

   Wells 4, 11, and 20

4. Well out of service due to excessive sand production:

   Well number 29.

Known well locations are shown on Figure Number 5. The appropriate location of abandoned or destroyed wells on the Base are shown on Figure 6.

Water well construction at McClellan has principally been accomplished using direct mud rotary drilling equipment. Exceptions to this methodology were in the construction of well number 29 which was accomplished using the reverse rotary drilling method and wells number 17 and 28 which were constructed using the cable tool percussion drilling method. The rotary construction practice resulted in a well completion design that provided for a sanitary surface seal, normally to a

depth of 50 feet or less, steel casing from the surface to the total depth of well, milled slot perforations opposite the selected aquifers to be pumped, and a gravel envelope placed in the annulus between the drilled hole and the well casing. Appendix D contains drawings illustrating the known lithology and completion details of each well constructed at McClellan.

The design of the majority of wells on the Base preceeds the current state of the art for engineering hydraulically efficient, sand free well structures. The size of the perforations and the selection of gravel packing materials, which today are carefully mated to each aquifer formation, were at the time of base well construction, normally selected based upon available local sources of well casing and gravel pack materials. Because of this practice, a large percentage of the existing base wells produce sand when pumping. To control the discharge of sand, sand separators are found on the majority of installations.

The gravel pack materials used in Base well construction ranged from 1/4 to 3/4 inch in size and are highly permeable. As a result, today, the annulus of each well serves as a potential conduit for the transfer of water between the shallow and deeper aquifers throughout the base.

Details of the known data for each well installation are contained in Appendix D. A summary description of each installation is as follows:

<u>Well Number 1</u>

Well 1 (Building 231) is one of the original Base wells and was drilled in 1937. Total depth of the well is 400 feet. The sanitary seal consists of 39

feet of 24 inch diameter casing, sealed in place with 32 feet of sealing clay and 7 feet of neat cement placed at the depth of 32 to 39 feet. The production casing is 12 inch steel, set to a depth of 400 feet, with perforations at 162 to 174 feet; 233 to 236 feet; 247 to 252 feet; 263 to 266 feet; 276 to 294 feet; 338 to 357 feet; and 378 to 396 feet. Perforations consist of milled slots, 6 inches long by 1/4 inch wide, six perforations per row, one row per foot, with copper wire mesh welded around the circumference of the casing opposite the perforated sections. The well is gravel packed from the surface to 400 feet with 1/4 to 3/8 inch gravel.

The well is equipped with a Peerless oil lubricated lineshaft deepwell turbine pump designed to produce 1400 gpm. Major components of the installation include:

1-100 HP 1800 RPM VHS Peerless Moturbo Motor

1-Peerless combination auxilary right angle gear drive assembly

1-Peerless Moturbo discharge head

160 feet of 10 inch oil lubricated column assembly

1-bowl assembly

1-GMC 671 Diesel auxiliary engine

1-100 HP electrical service

The well and pump are located in a 20 by 20 foot concrete pump house (Building 231). Access to the pump is through an 8 foot square opening in the building roof.

The pump station was indefinitely removed from service on March 27, 1980 due

to the presence of TCE.

Well Number 2

Well 2 (Building 232) was constructed in 1937, as one of the original base wells. Total depth of the well is 298 feet (a 10 inch test hole was drilled to 405 feet). The sanitary seal consists of 40 feet of 24 inch diameter casing, sealed from ground level to a depth of 33 feet with sealing clay and from 33 feet to 40 feet in depth with neat cement. The production casing is 12 inch steel, set to a depth of 298 feet, with perforations at 100 to 112 feet; 141 to 158 feet; 180 to 197 feet; and 282 to 296 feet. Perforations consist of milled slots, 6 inches long by 1/4 inch wide, six perforations per row, one row per foot, with copper wire mesh welded around the circumference of the casing opposite the perforated sections. The well is gravel packed from the surface to 298 feet with 1/4 to 3/8 inch gravel.

The well is equipped with a Floway, oil lubricated lineshaft turbine pump that produces approximately 400 gpm. Major components of the installation include:

1-50 HP 1800 RPM VHS electric motor
1-Floway discharge head
152 feet of 8 inch oil lubricated column assembly
1-bowl assembly
1-50 HP electrical service

The well and pump are located in a 20 foot square concrete building (number

232). The building is 9 feet high and access is through an 8 foot square section of removable roof.

The pump station was indefinitely removed from service on November 23, 1979 due to the presence of TCE.

Well Number 3

Well 3 (Building 663 area) has been abandoned by the Water Department personnel. The well was formerly a farm well that existed at the time of McClellan Air Force Base land aquisition. No known records delineating construction details have been found nor was any physical structure noted during field surveillance. It is not known how this well was abandoned. A general location of this well is shown on Figure 7.

Well Number 4

Well 4 is located adjacent to the Winstead Athletic Field. Total depth of the well is 382 feet. The sanitary seal consists of 81 feet of 24 inch diameter steel casing. No sealing material is shown on Air Force drawings (AF drawing no. 6870-247-1). The production casing is 12 inch diameter steel, set to a depth of 382 feet; with perforations (type unknown) commencing at 169 feet and continuing for the entire length of the casing. The well is gravel packed (size unknown) throughout its entire depth.

The well is equipped with a Byron Jackson pump, details of which are unknown.

The pump station is presently utilized for irrigation standby only and has not been run in several years.

Well Number 5

Well 5 (also referred to as the "Old River Dock" well), is off site, located adjacent to the Garden Highway several miles southwest of the study area, and therefore is beyond the scope of this review.

Well Number 6

Well 6 has been reported by the Water Department personnel to be an "old farm well" that existed during the early McClellan Air Force Base land acquisition period. No known records delineating construction details have been found nor was any physical structure noted during field surveillance. It is not known how this well was abandoned. A general location of this well is shown on Figure 7.

Well Number 7

This well is located in the Building 489 area, which contains the engine test shops and previously housed the reciprocating engine repair shops. These shops produced a considerable amount of phenols which apparently entered and contaminated the well. Subsequently the well was capped, the pump and equipment removed, and the excavation was filled.

This well was 398 feet deep and was cased with 12-inch pipe for the full length. A surface pipe was installed to 50 feet and was cemented from 25 to 50 feet. It is assumed that phenol-laden waste water entered the well, probably alongside the shallow surface casing, and created tastes and/or odors which could not be tolerated.

This well has been abandoned and plugged.

Well Number 8

Well 8 (Building 91) was constructed in July of 1942. Total depth of the well is 785 feet. A sanitary seal consists of 43 feet of 24 inch diameter casing, sealed in place with 25 feet of concrete placed at the depth of 18 to 43 feet. The production casing is 12 inch 10 gauge double steel casing set to a depth of approximately 625 feet. Casing perforations and gravel pack details are not noted in McClellan records.

The well is equipped with a Peerless oil lubricated lineshaft turbine pump which produces approximately 1050 gpm. Major components of the installation include:

1-100 HP 1800 RPM VHS electric motor

1-FMC Peerless combination right angle gear drive

1-Peerless Moturbo discharge head

170 feet of 10 inch oil lubricated column assembly

1-bowl assembly

1-Climax Blue Streak gasoline engine

1-100 HP electrical service

The well and pump are located in a 27 foot by 15 foot concrete pumphouse (Building 91). Access to the pump is through a 10 foot square opening in the building roof.

This pumping station is presently in service.

Well Number 9

Well 9 (see Figure 7) was constructed in July of 1953. Review of base records did not indicate the construction details of this well; however, the Corp of Engineers' field report, compiled during test hole drilling, indicates this well could have been 660 feet deep.

It is reported that this well subsequently collapsed and was replaced with Well No. 20. Records do not indicate the method, if any, of well abandonment.

Well No. 10

Well 10 (Building 93) was constructed in 1945. Total depth of the well is 400 feet. No information was available as to the construction details of the sanitary seal. The production casing is 14 inch diameter steel with a reduction to 12 inch steel at a depth of 144 feet. Perforations (type unknown) were installed from 170 feet to 392 feet although there is a subsequent notation in the file (unconfirmed) that the perforations may start at 145 feet.

The well is equipped with a Peerless oil lubricated lineshaft deepwell pump which produces approximately 1050 gpm. Major components of the installation include:

1-100 HP 1800 RPM VHS electrical motor

1-FMC Peerless combination right angle gear drive

1-FMC Peerless discharge head

100 feet of 10 inch oil lubricated column assembly

1-bowl assembly

1-Climax Blue Streak gasoline motor

1-100 HP electrical service

The well and pump are located in an 8 foot by 25 foot concrete pumphouse (Building 93). Access to the pump is through a 4 foot square access opening in the roof.

The well is presently in service.

Well Number 11

Well 11 (Building 2100) was constructed in 1945. Total depth of the well is reported to be 395 feet. No information is available as to the type and depth of the sanitary seal. The production casing is reported to be 14 inch diameter steel with a reduction to 12 inch steel at 140 feet. Perforations (type unknown) commence at 154 feet and are presumed to terminate at the total depth of the well (395 feet). Photologs performed by Laval in 1970 were unable to ascertain construction features below 346 feet due to "cloudy water". This well is thought

to be gravel packed; however, no details of gravel pack type or depths were available.

The well is equipped with a Peerless oil lubricated lineshaft turbine pump. No production records were available to ascertain its capacity. Major components of the installation include:

1-Caterpillar turbocharged diesel engine

1-Peerless combination right angle gear drive

1-Peerless moturbo discharge head

140 feet of 10 inch lubricated lineshaft column assembly

1-bowl assembly

The well and pump are located in a 15 by 25 foot concrete pump house (Building 2100). Access to the pump is through a 4 foot square opening in the roof.

This well is in service; however, it is generally only used during periods of peak demand.

Well Number 12

Well 12 (Building 395) was drilled to a depth of 390 feet. The year of construction could not be ascertained from available records. The sanitary seal consists of approximately 80 feet of 24 inch diameter casing. Information as to sealing clay or cement used for the sanitary seal is not available. The production casing is 12 inch diameter steel set to a depth of 390 feet with

perforations (type unknown) commencing at 164 feet and terminating at 384 feet (Well Tech video log of 1973). No information as to the size or type of gravel pack was found.

The well is equipped with a Peerless oil lubricated turbine pump which produces approximately 1050 gpm. Major components of the installation include:

1-100 HP 1800 RPM VHS electric motor

1-Peerless combination right angle gear drive

1-Peerless Moturbo discharge head

140 feet of 10 inch oil lubricated lineshaft column assembly

1-bowl assembly

1-Climax Blue Streak gasoline engine

1-100 HP electrical service

The well and pump are located in a 8 by 25 foot concrete pumphouse (Building 395). Access to the pump is through a 4 foot square opening in the building roof.

The pump station was indefinitely removed from service on August 28, 1980 due to the presence of TCE.

Well Number 13

Well 13 (Building 614) was constructed in 1945. Total depth of this well is 391 feet. No information is available as to the construction details of the sanitary seal. The production casing is 14 inch steel and reduces to 12 inch

steel at 147 feet. Perforations (type unknown) begin at 178 feet and are believed to terminate at the total depth of the well. No information on the gravel pack type or size is available.

The well is equipped with a Peerless oil lubricated lineshaft turbine pump which produces approximately 1100 gpm. Major components of the installation include:

1-100 HP 1800 RPM VHS electrical motor

1-Peerless combination right angle gear assembly

1-Peerless Moturbo discharge head

160 feet of 10 inch column assembly

1-bowl assembly

1-GMC 671 diesel auxiliary engine

1-100 HP electrical service

The well and pump are located in a 15 foot by 24 foot concrete pump house (Building 614). Access to the pump is through a 4 foot square opening in the roof.

This well is presently in service.

Well Number 14

No information exists as to the location, size, abandonment or destruction of this well.

Well Number 15

Well 15 is located at the corner of Whitney and Eastern Avenue, which is off-site and therefore beyond the scope of this review.

Well Number 16

Well Number 16 has been reported by the Water Department personnel to exist in the vicinity of the northwest side of Building 440. This well is believed to have served Building 440 only. The present status of this well is unknown. No construction details are available. The reported location of this well is shown on Figure 7.

Well Number 17

Well 17 (Building 699) was originally constructed by the cable tool method to a depth of 930 feet with 16 inch casing to a depth of 720 feet and 12 inch casing in the balance of the hole. Records indicate the well was sealed in 1947 to a depth of 390 feet. A video scan was performed in 1971 showed that the present depth of the well is 353 feet. Presently no information is available on the sanitary seal. Production casing is 16 inch diameter steel to a depth of 353 feet. Perforations (type unknown) are installed at the depths of 216 to 224 feet; 286 to 294 feet; and 302 to 312 feet.

The well is equipped with a Floway oil lubricated lineshaft turbine pump which produces approximately 1100 gpm. Major components of the installation include:

1-75 HP 1800 RPM VHS electric motor

1-Floway discharge head

150 feet of 8 inch oil lubricated column assembly

1-bowl assembly

1-75 HP electrical service

1-Auxiliary engine (not connected at this time)

The well and pump are located in a 36 foot by 20 foot concrete pumphouse (Building 699). Access to the pump is through a 4 foot square opening in the roof.

This well is presently in service.

Well Number 18

Well 18 (Building 664) was constructed in February 1953. Total depth of the well is 408 feet. The sanitary seal consists of a 30 inch diameter casing set to 50 feet and sealed with 50 feet of cement grout. The production casing is 14 inch diameter steel set to a depth of 408 feet with perforations (type unknown) at 169 to 185 feet; 210 to 260 feet; 304 to 349 feet; and 378 to 387 feet. The gravel pack material was installed from ground level to 408 feet; the type of material is unknown.

The well is equipped with a Johnson oil lubricated lineshaft turbine pump which produces approximately 1225 gpm. Major components of the installation include:

1-150 HP 1800 RPM VHS electric motor

1-Johnson combination right angle gear assembly

160 feet of 8 inch oil lubricated column assembly

1-bowl assembly

1-Climax gasoline auxiliary engine

1-150 HP electrical service

The well and pump are located in a 15 by 35 foot concrete pumphouse (Building 664). Access to the pump is through a 4 foot square opening through the building roof.

This pump station was indefinitely removed from service on June 9, 1981, due to the presence of TCE.

Well Number 19

Well 19 (located in Building 663 area) was constructed in 1952 and completed to a depth of 360 feet. No information is available on the sanitary seal. The production casing diameter was not recorded; however, records indicate it was perforated (type unknown) from 174 to 193 feet; 214 to 239 feet; and 305 to 360 feet. No information was available on the gravel pack. The reported location of this well is shown on Figure 7.

This well was reported to have collapsed and is no longer in use. Details of the methods used to abandon the well are unknown.

Well Number 20

Well 20 (parking lot of Building 200) was constructed in 1968. Total depth of this well is presumed to be approximately 600 feet. No information is available on the sanitary seal. The production casing is 14 inch diameter steel with perforations (1/8 inch x 3 inch) at 178 to 190 feet; 234 to 274 feet; 338 to 374 feet; 494 to 506 feet; and 564 to 598 feet. No information is available on the gravel pack.

The well is equipped with a Johnson oil lubricated lineshaft turbine pump. Major components of the installation include:

1-75 HP 1800 RPM VHS electric motor

1-Johnson discharge head

100 feet of 4 inch lubricated column assembly

1-bowl assembly

1-75 HP electrical service

This well and pump are enclosed in an underground concrete vault which is approximately 8 feet square.

This well is presently a standby source of water to Building 200.

Wells Number 21 through 24

Wells 21 through 24 are reported to be located in the areas of Building 696, Building 1440, Building, and Building 1465 respectively. These wells have been

reported by the Water Department personnel to be "old farm wells" that existed during the early McClellan Air Force Base land acquisition period. No known records delineating construction details were found. It is not known if these wells were abandoned or destroyed. A general location of these wells is shown on Figure 7.

Well Number 25

Well 25, also known as the Lincoln Communication Site Well, is several miles east of the study area, and therefore is beyond the scope of this review.

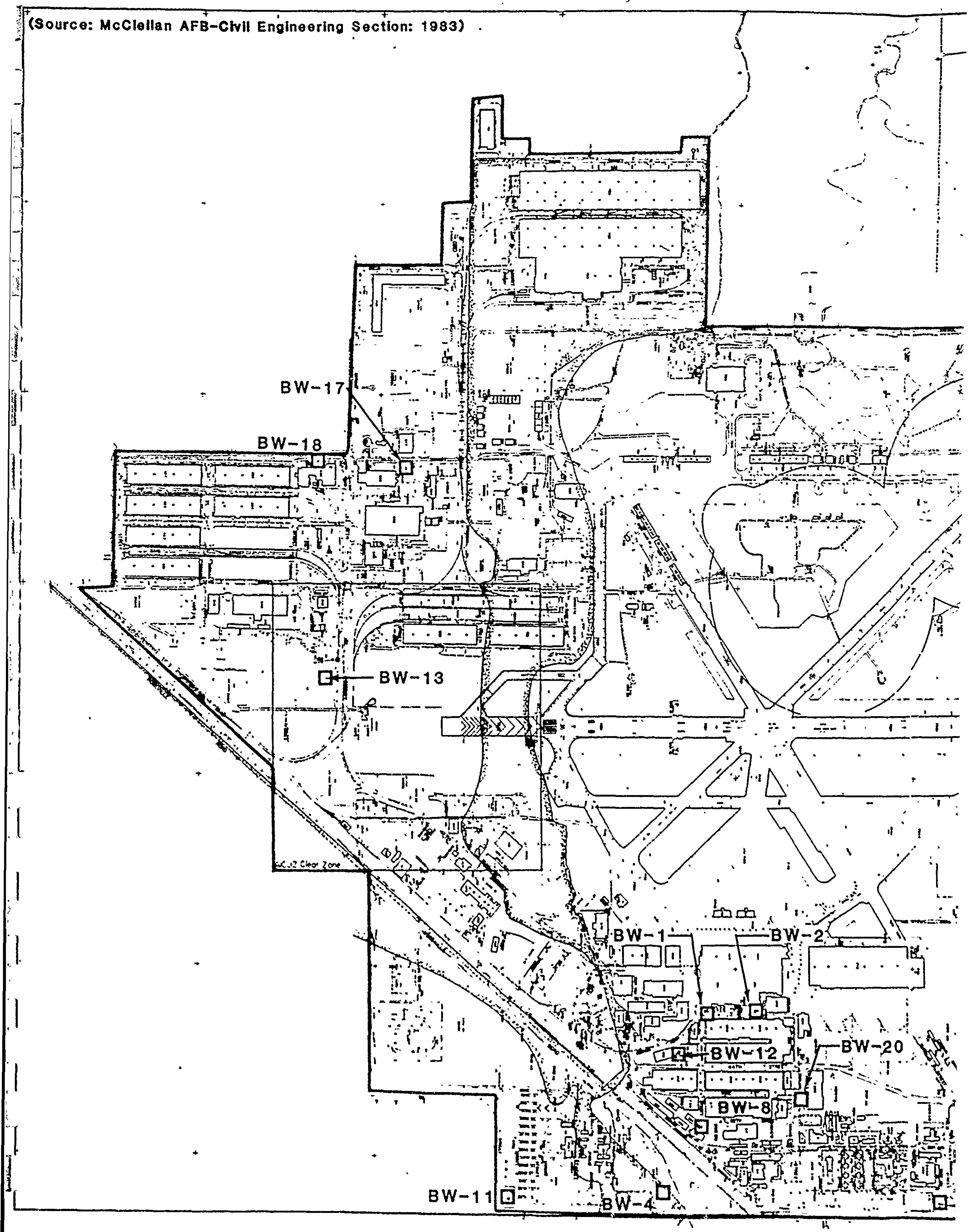
Well Number 26

Well 26, also known as the Davis Communication Site Well, is several miles southwest of the study area, and therefore is beyond the scope of this review.

Well Number 27

Well 27, used to serve the Rapcon Facility, was constructed to a depth of 260 feet in June of 1962. The sanitary seal consists of a 12 inch casing, cement grouted in place to a depth of 61 feet. The production casing is 6 inch diameter steel to the total depth with perforations (3/16 inch x 1 1/2 inch milled slot) at 175 to 185 feet; 200 to 210 feet; and 240 to 260 feet. The gravel pack (type not specified) was installed to the total depth of 261 feet.

This well is presently capped with a "well seal" and no longer in use. The location of this well is shown on Figure 7.


(Source: McClellan AFB-Civil Engineering Section: 1983)
BW-17
BW-18
BW-13
BW-1
BW-2
BW-20
BW-12
BW-8
BW-11
BW-4

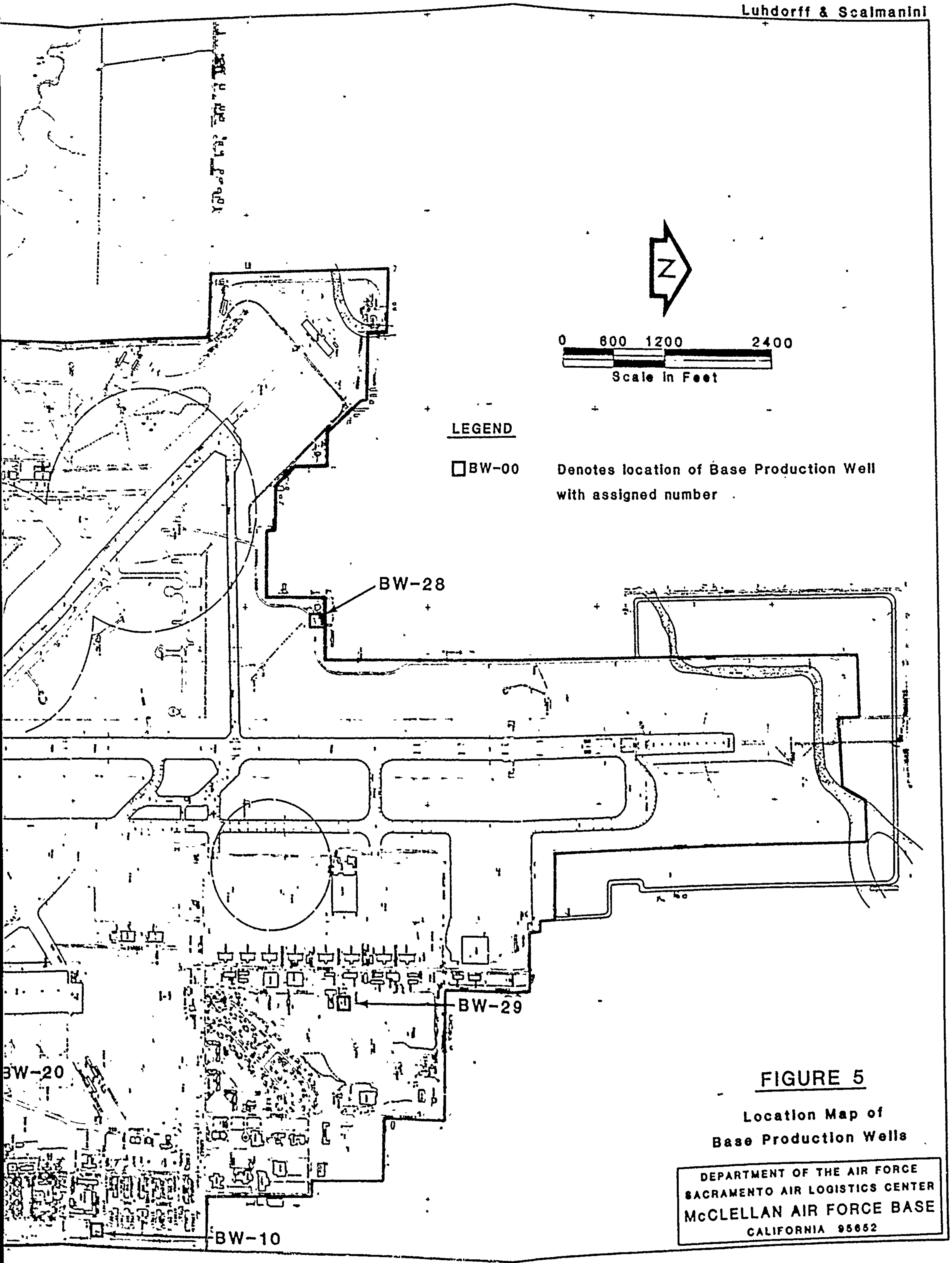


FIGURE 5

Location Map of Base Production Wells

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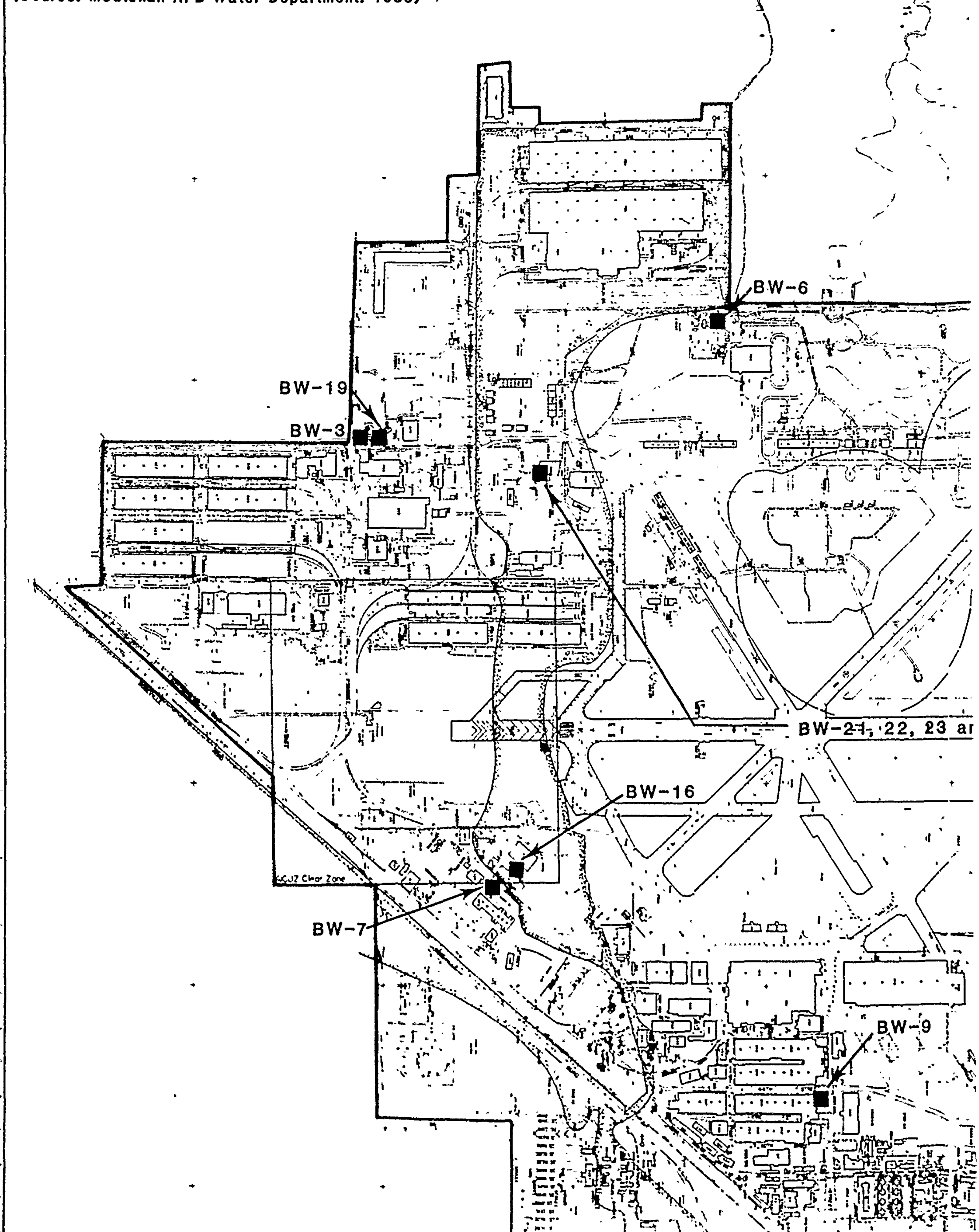
(Source: McClellan AFB Water Department: 1983)



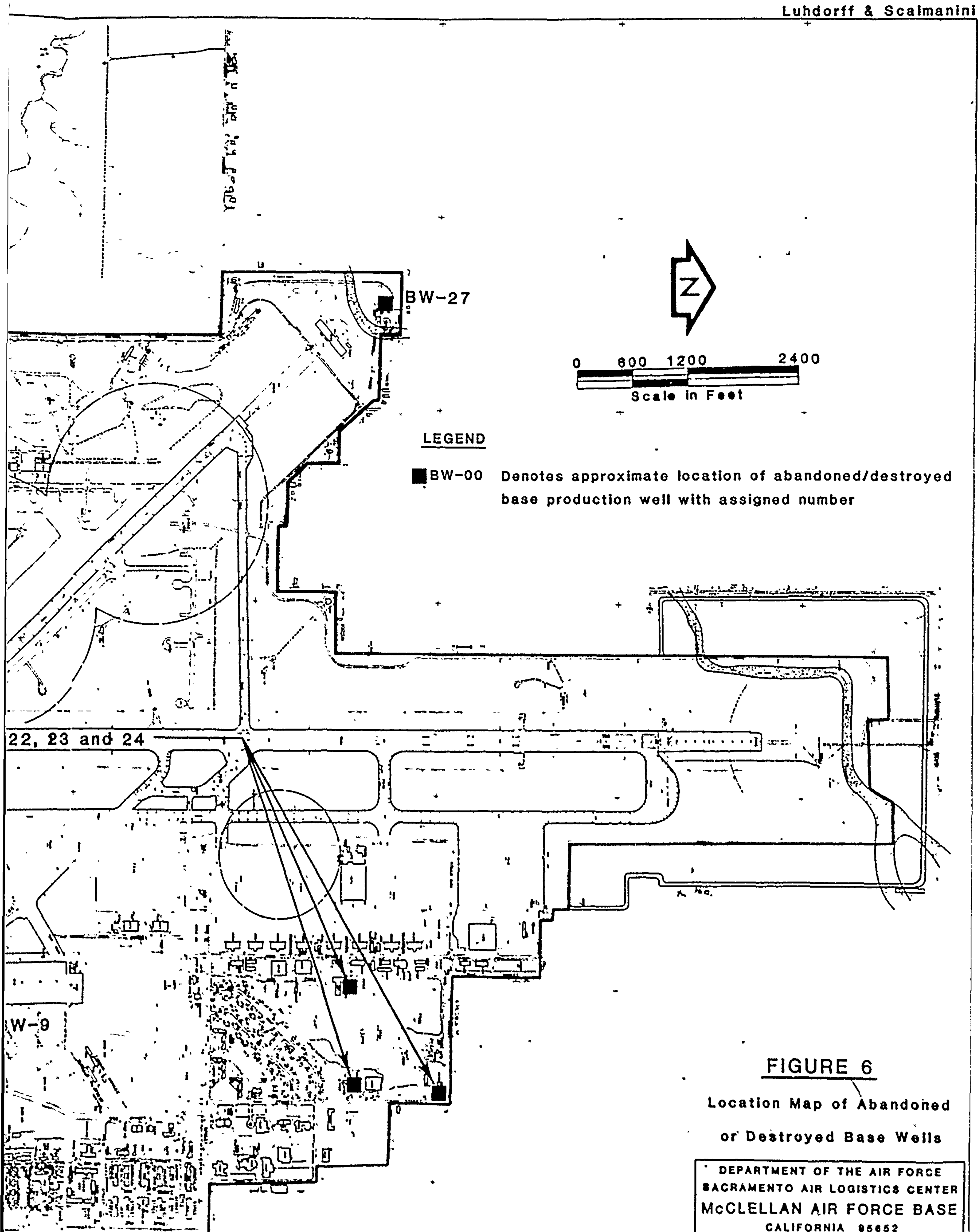


FIGURE 6

Location Map of Abandoned or Destroyed Base Wells

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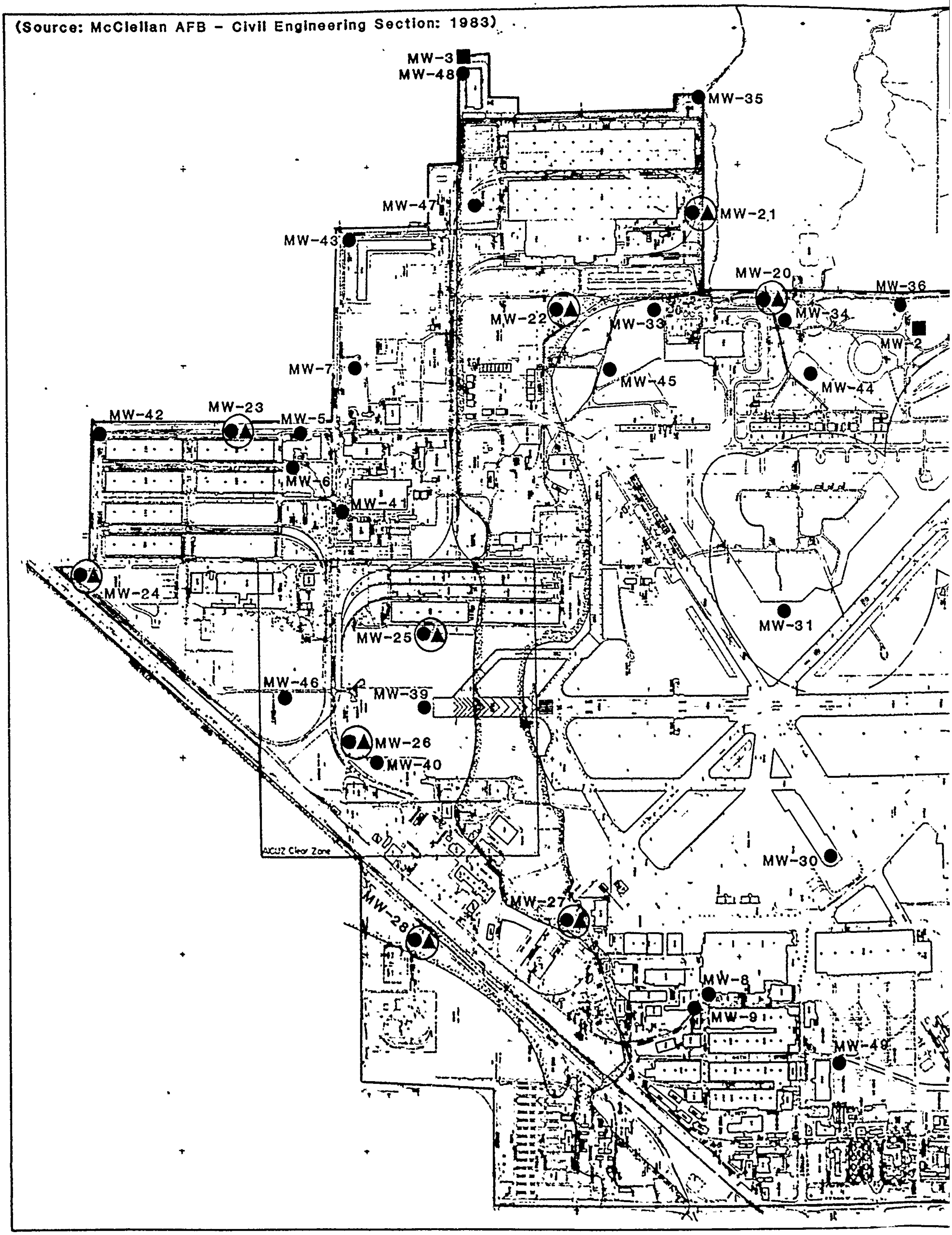
(Source: McClellan AFB - Civil Engineering Section: 1983)
MW-3
MW-48
MW-35
MW-47
MW-21
MW-43
MW-20
MW-36
MW-22
MW-33
MW-34
MW-2
MW-7
MW-45
MW-44
MW-42
MW-23
MW-5
MW-6
MW-41
MW-24
MW-31
MW-25
MW-46
MW-39
MW-26
MW-40
MW-30
MW-27
MW-28
MW-8
MW-9
MW-49

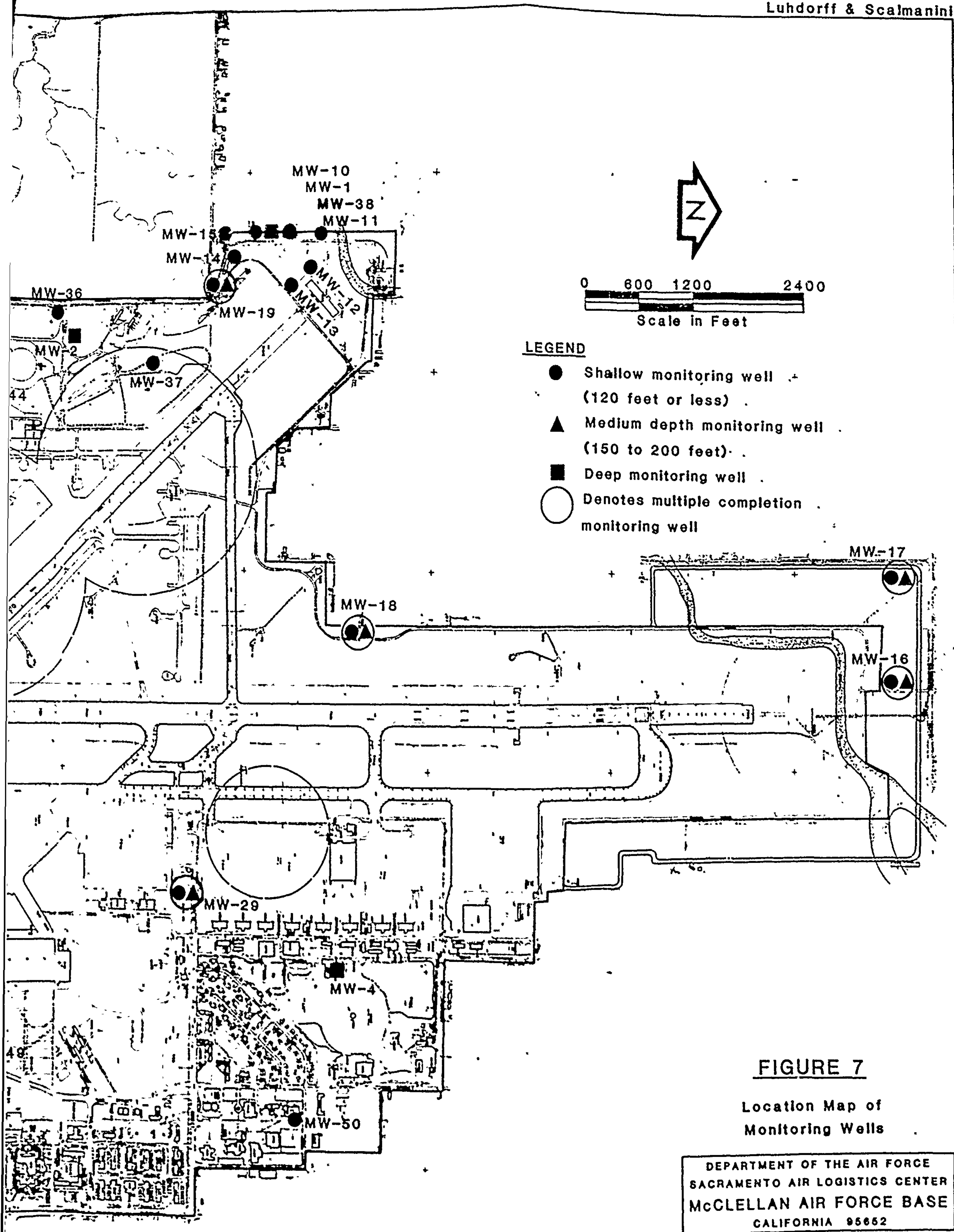

FIGURE 7

Location Map of Monitoring Wells

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Well Number 28

Well 28 (adjacent to Building 1082) was constructed in 1968, using cable tool drilling equipment. Total depth of the well is 236 feet. A sanitary seal was installed to a depth of 72 feet with cement grout installed from 0 to 60 feet. The production casing is 8 inch steel, "driven" to a depth of 236 feet, with perforations at 144 to 147 feet; 205 to 212 feet; and 233 to 236 feet. The well was not constructed with a gravel pack.

The well pump is a 2 HP Town and Country submersible pump which produces approximately 30 gallons per minute.

This well is presently in service.

Well Number 29

Well 29 (Building 1455) was constructed in 1981, using reverse rotary drilling equipment, to a total depth of 604 feet. A sanitary seal, consisting of cement grout, is installed between the production casing and the borehole, from ground level to a depth of 53 feet. The production casing is 16 inch diameter steel (3/16 wall to 251 feet and 1/4 wall to 575 feet) and was installed to a total depth of 575 feet. It is reported that louvered perforations were installed, with 1/16 inch slots utilized from 251 to 401 feet and 3/32 inch slots utilized from 401 to 555 feet. Two gravel pack mixtures were utilized: Schwartzgruber 2:1 mix was installed from 53 feet to 386 feet and Schwartzgruber 3:1 mix installed from 386 to 604 feet.

The well pump consisted of a Peerless oil lubricated vertical turbine pump which was designed to produce approximately 1200 gallons per minute. Major components of the installation include:

1-125 HP 1800 RPM VHS electric motor

1-Randolph combination right angle gear assembly

1-Peerless discharge head

180 feet of 10 inch oil lubricated column assembly

1-Peerless 6 stage 12 MB bowl assembly

1-125 HP electrical service

The building, as of this writing, is removed.

The well and pump have been indefinitely removed from service. The well was reported to have produced copious amounts of sand.

The foregoing discussion has described the known construction features of all production wells. Sealing requirements for production wells are contained in Chapter 3.

Base Monitoring Wells

Monitoring wells have been constructed since 1980 at McClellan to identify the extent of groundwater contamination. Two separate programs of construction were employed. The first drilling activity was performed under the direction of the McClellan Groundwater Contamination Committee in its initial phase of

contaminant investigation. The second drilling program was under the direction of Engineering-Science during their Phase II - Confirmation Study. The vast majority of monitoring wells (Figure 7) were constructed in a manner which would prevent the vertical communication between aquifers encountered during construction. Details of all monitoring well designs are contained in the Phase II Confirmation Study prepared by Engineering Science. Of interest to this study are those monitoring wells which, by their method of construction, provide the potential for vertical communication. Identified monitoring wells which could provide a conduit for contaminant movement are the initial nine wells (wells MW1 through MW9) which were constructed on the base. Appendix D describes the construction and lithology of each of these wells.

Monitoring well number 1 was accidently completely filled with clay and cement in an earlier attempt to reduce the potential for communication between aquifers. Well number 2 is reportedly filled to a depth of 120 feet. Wells 3 and 4 remain as originally constructed. Monitoring wells MW5 through MW9 were constructed in 1980 during the early soil investigations by McClellan's staff and have not been altered since their installation. The wells were constructed by installing four inch casing in the boreholes used for soil testing, with each well being sealed to a depth of twenty feet. Perforated casing was installed from twenty feet to the bottom of well. The depths of the wells range from 110 feet to 140 feet and as such they intersect the shallow aquifers and potentionally the deep aquifers underlying the base. Recommended sealing procedures for the monitoring wells are discussed in Chapter 3.

CHAPTER 3

SEALING OF BASE WELLS

CHAPTER 3

SEALING OF BASE WELLS

Previously cited investigations have identified the potential for the contaminated shallow groundwater underlying McClellan to migrate to the deeper aquifers and into the production wells through the permeable gravel envelopes of Base production and monitoring wells. The mitigation of this concern is addressed in this chapter. The initial discussion presents the concerns that should be addressed in any subsurface sealing operation. It is followed by a review of well cementing techniques, the selected methodology as proposed by LSCE for McClellan, the base wells to be sealed, and finally, a review of the well sealing recommendations furnished by ES in the Phase II Confirmation Study.

Subsurface Sealing Concerns

Well sealing, or as it is more commonly referred to in the well industry, "well cementing", is the process of artifically reducing or eliminating the permeability around the casing of a well at some selected depth.

Virtually any well, whether it be water production, monitoring, injection, oil or gas, needs to be cemented. Cementing is the common term for the process of placing a slurry, usually formed by combining a cementatious material with a liquid, into the annulus between the outside of the casing and the wall of the drilled hole. Placement of cement is usually done by pumping.

The oil, gas and water well industries use cementing techniques to accomplish a wide variety of tasks:

- -bond and support casing
- -restrict fluid movement between formations to prevent contamination of one zone by another
- -protect casing from corrosion due to subsurface mineralized waters and electrolysis
- -seal lost circulation or thief zones.

Cementing to accomplish the above objectives is normally performed during the initial well construction. The drilling industry refers to such cementing operations as "primary cementing."

Another type of cementing operation is usually remedial and is known as "secondary cementing." It involves operations performed after the well has been completed. The most common remedial operation is known as "squeeze cementing." This is the process of applying hydraulic pressure to force or squeeze a cement slurry into a formation void or against a porous zone from within a cased well. Squeeze cementing is commonly used to accomplish the following tasks:

- -segregate production zones
- -repair casing leaks
- -seal off lost circulation zones
- -correct a defective primary cementing job
- -prevent fluid migration from abandoned zones or wells

The McClellan wells to be sealed will require a secondary cementing procedure that is designed to isolate two aquifer systems which have been referred to in previous investigations as the "shallow" and "deep" aquifers underlying the Base. To be effective as a seal, the placement of cement must be opposite a low permeability structure such as a clay member. Placement of the cement slurry opposite a more permeable structure, such as a sand formation, would not alter the downward movement of the contaminants, only their pathway to the lower aquifers. Figure 8 illustrates the placement of cement opposite permeable and low permeable structures with the resulting allowable pathway of the contaminated water after placement.

To be successful in sealing operations requires a detailed understanding of the lithology at each well site. Once lithology is known, the location for an effective seal placement can be selected. The available lithologic data for the majority of wells at McClellan consists of driller's logs, which are logs written at the time of well construction by the water well drilling contractor, based upon his interpretation of the drill cutting returns. These logs, while informative, are generally not sufficiently accurate to define the most desirable location for the placement of well seals. A more accurate procedure is to combine a lithologic log, developed from the collection of drill cuttings, with a geophysical log run in the bore hole. The geophysical log or suite of logs which would include, as a minimum, one or more resistivity logs and a spontaneous potential log, accurately indicate the location of permeable and less permeable formations. Three wells at McClellan were constructed utilizing such logs (wells 18, 19 and 29). A comparison of the driller's log and the electric log (a combination resistivity and spontaneous potential log) for well 18 illustrates the importance of proper logging techniques. Figure 9, the electric log for well

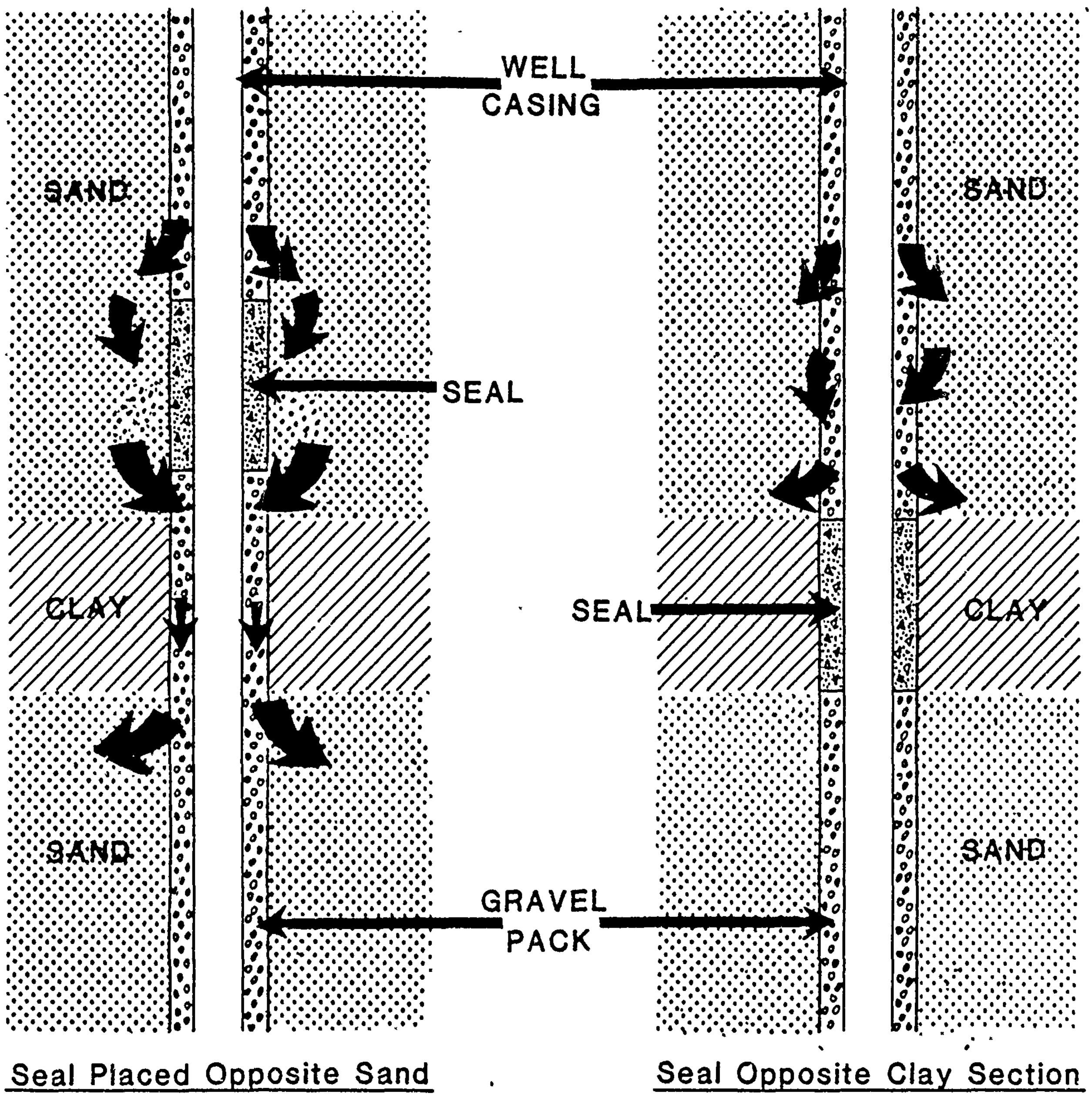

FIGURE 8

Contaminent Movement After Sealing

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18 indicates two thin clay formations which are separated by highly permeable sand lenses. Also noted on figure 9 is the driller's log for the same well. The two clay sections, located at depths of 92 and 115 feet on the electric log offer the only assured points for sealing of the gravel pack. Review of the driller's log does not permit this accurate identification.

The practice of geophysical logging is now widely implemented in the water well industry for new well construction and is commonly used in most groundwater contamination investigations. Omitted in the Phase II Confirmaion Investigation was the use of this logging technique. Had the logs been run in selected deep soil borings, the ability to corrolate formations encountered from well to well would have been substantially enhanced.

In the Phase II investigation it was concluded that water bearing formations between 80 and 120 feet should be sealed. Examination of the electric log for well 18 notes the presence of alternating sequences of sand, silt and clay from 80 feet to 155 feet. Below 155 feet are highly permeable formations of the Fair Oaks sequence which have been developed for groundwater supplies from this well. Concerns must be raised as to the quality of the groundwater in the formations immediately below the clay formations located at 115 feet, as well as those above, prior to sealing. To determine these and other factors at each well site, it is very important to preceed actual well sealing operations with a preliminary geophysical site investigation which will define water quality, piezometric heads of the individual formations, their ability to communicate with other aquifers, and finally, the specific area of the well structure to install a seal. This information is discussed in detail later in this chapter in the section referred to as "Preliminary Site Investigation."

Luhdorff & Scalmanini

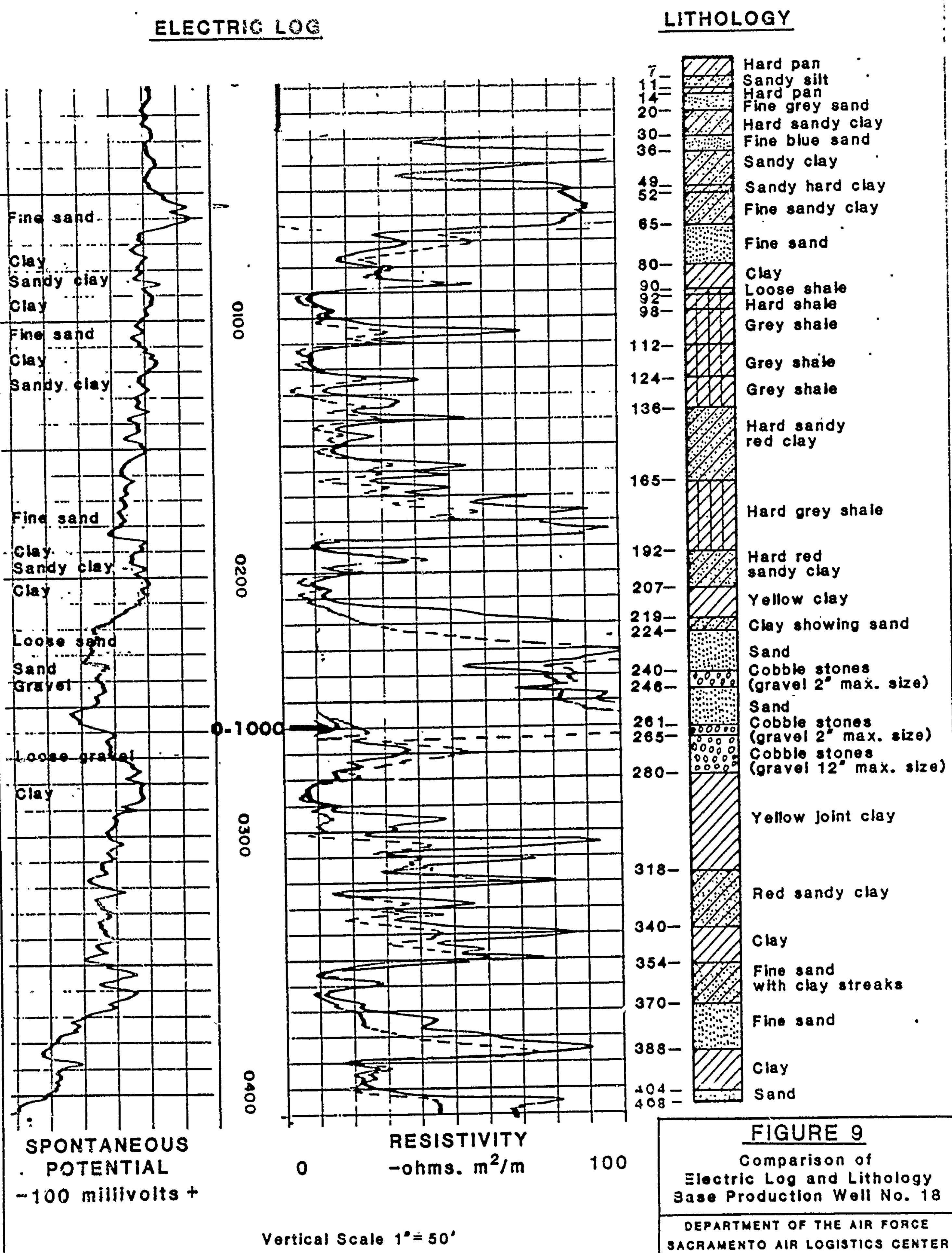

FIGURE 9

Comparison of
Electric Log and Lithology
Base Production Well No. 18

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Well Cementing Techniques

The procedures to effectively install proper well seals in constructed wells have been developed and refined over the past forty years, principally by the oil and gas well industry. In the remedial cementing operations at McClellan, the placement of the cement can be theoretically accomplished by two approaches to sealing. The first would be to access the area to be cemented from outside the well's casing and the second technique approaches the area to be sealed from within the casing. The two procedures may be described as follows:

1. Cementing from Outside of the Casing.

The procedure of installing cement seals by accessing the area to be sealed from outside of the well's casing is the most common method of cementing in primary cementing operations, during initial well construction. Normally this practice is accomplished in an open annulus between the well bore and casing. Drill pipe or a special cementing string is run to the depth desired for sealing. Cement slurry is then pumped from the surface down the pipe assembly. The drill pipe is maintained within the slurry as pumping proceeds to avoid cement separation.

Successful secondary or remedial cementing operations have been achieved in completed wells using this technique by drilling from the surface through the gravel pack material to the selected depth for sealing using direct circulation, mud rotary drilling equipment. On reaching the area to be cemented, the drilling tools are removed and replaced with a cementing string. Cementing operations

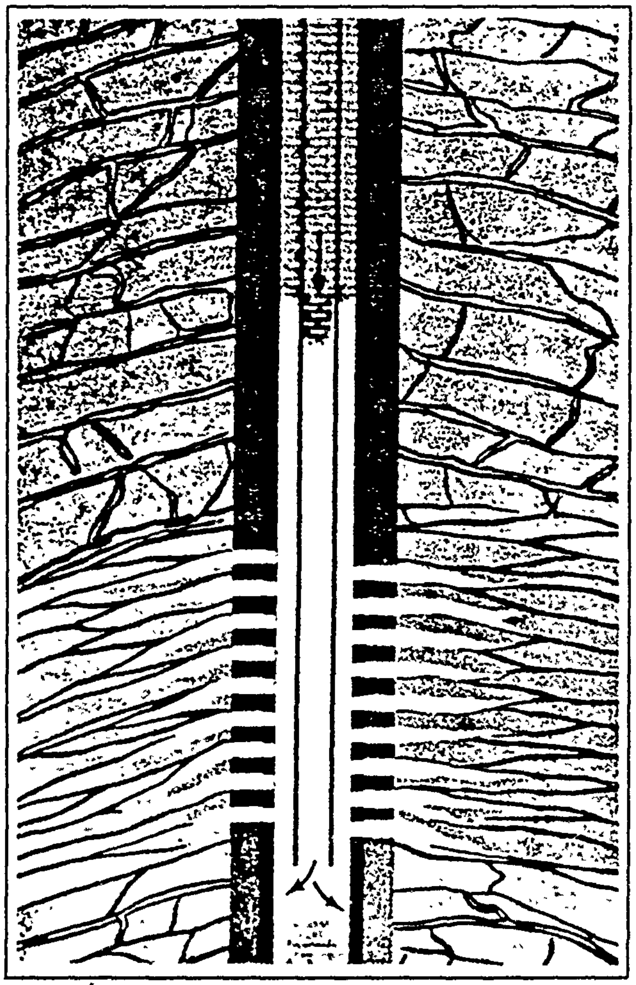
then proceed similiar to the previously discussed primary cementing techniques.

2. Cementing from Within a Casing String.

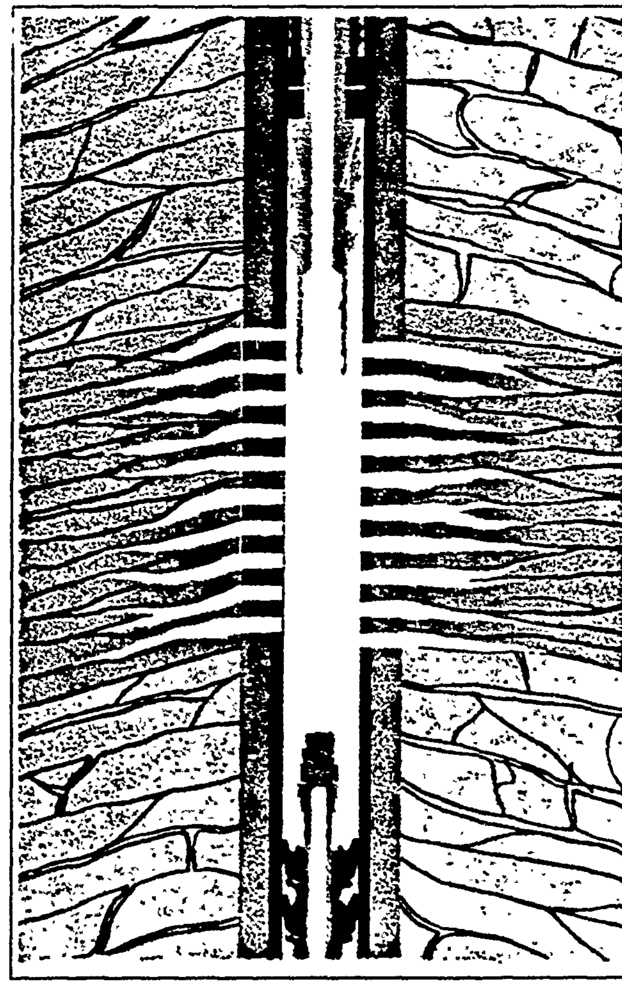
The secondary cementing procedure of squeeze cementing from within a cased well to effect remedial cementing is the primary sealing method employed by the well industry. The process involves applying hydraulic pressure to force or "squeeze" a cement slurry through perforations in the casing at the depth selected for sealing. Two modifications of the methodology are employed in this process: the Bradenhead method and the Packer method.

In the Bradenhead method, figure 10, the cement is pumped into the cased hole through tubing or drill pipe, displacing well fluid into the annulus through the perforations placed in the casing opposite the area to be sealed. The bottom of the sealing section within the casing is sealed by a removable packer, a bridge plug, or sand. After cement is placed across the zone to be squeezed, the tubing is removed from the well and the casing closed with a Bradenhead at the surface. A calculated volume of displacement fluid is then pumped into the casing, causing the cement to move into the zone to be sealed. After the cement is displaced, the slurry remaining in the casing can sometimes be removed by reverse pumping operations. Usually however, drilling is required to remove the cement.

The Packer method, Figure 10, is generally considered to be superior to the Bradenhead method of cementing in oilfield operations; however, it is seldom applied in water wells for effecting shallow seals. In this method, the interval to be squeezed is isolated within the casing by a packer, run and set on tubing



Bradenhead Squeeze Method



Squeeze Packer Method

FIGURE 10

Sealing Methods Typically Employed in Water Wells

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(Source: Halliburton Services: 1983)

at the top of the section to be sealed after setting a drillable or retrievable bridge plug below the perforations. The interval is then pressure grouted between the packers forcing or squeezing the cement into the annulus to be sealed. The procedure permits high squeeze pressures during cementing operations which are frequently required during deep remedial sealing operations. Following the cementing operations, the upper packer is removed from the well. The lower packer and remaining cement slurry is then removed from the well by drilling.

McClellan's production wells are principally older wells. As such, their steel casing assemblies can be expected to have some corrosion and possible deterioration from normal service use. Their ability to withstand internal or external loading is therfore unknown, but of concern when considering pressure cementing. Of the two remedial cementing procedures discussed, the Bradenhead method would be considered far safer to perform since it develops primarily internal pressures which are essentially equalized at the point of injection into the formation and normalized above the sealing point by the presence of the existing gravel pack material outside the casing. The Packer method often develops extremely high collapse pressure above and below the installed packers, which could result in casing failures at McClellan.

Preliminary Engineering Site Investigations

Preliminary engineering site investigations of each well designated for sealing should be accomplished prior to the final selection of wells to be actually sealed. The investigation should commence with the construction of a multiple piezometer monitoring well adjacent to each production well considered for sealing.

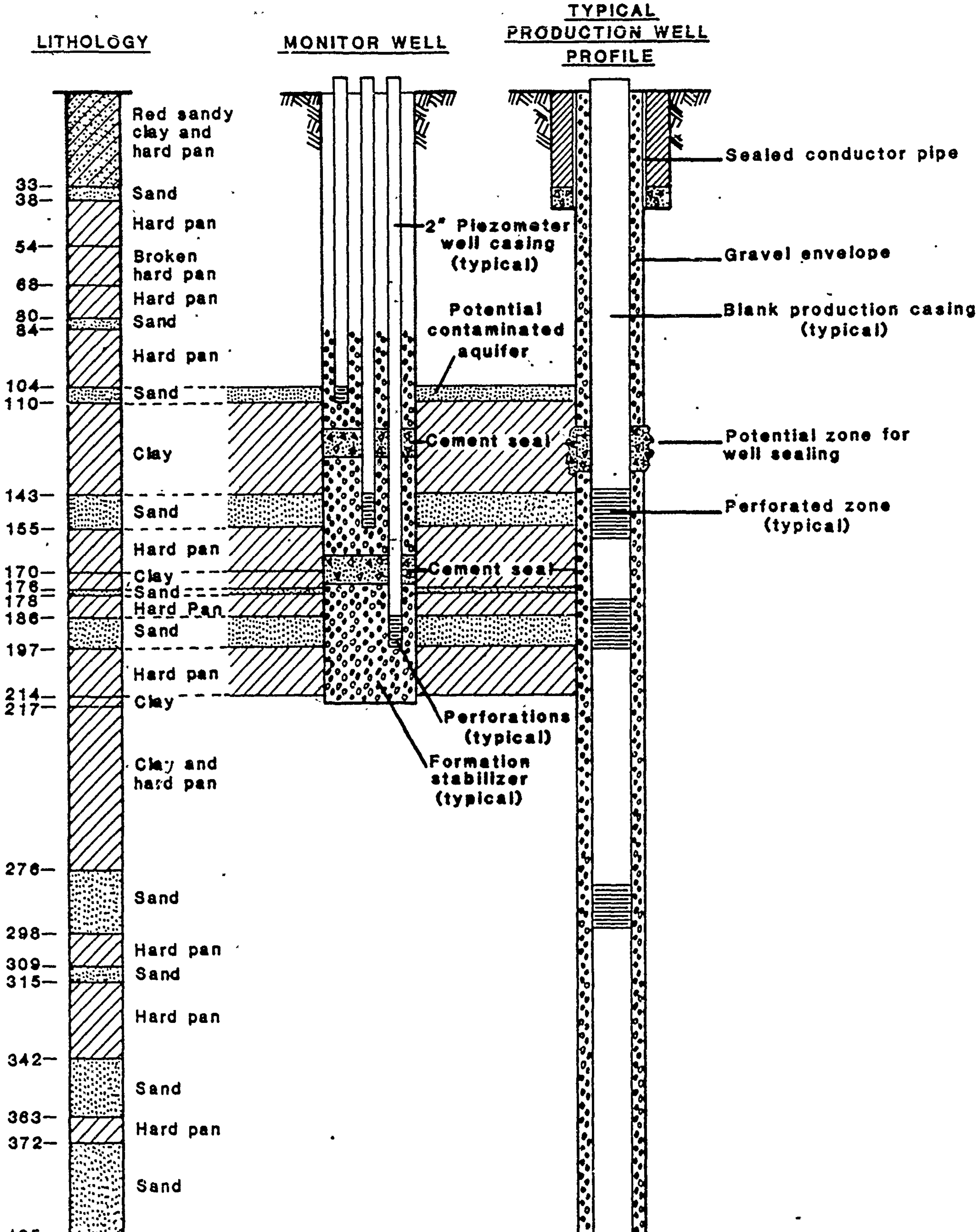

FIGURE 11

Typical Monitoring Well Construction Detail

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The monitoring wells, which would be located within 20 to 40 feet of the production well (Figure 11), would provide:

-geophysical and lithological logging

-piezometric water levels of the shallow and deep aquifers

-water quality data from each formation monitored

The construction and use of the monitoring wells prior to the selection of wells requiring sealing would provide the information necessary to define the necessity and the specific requirements for sealing of each well. Additionally, the monitoring wells would provide the only known method of determining the effectiveness of the sealing operations, once installed, and for monitoring aquifer performance in future years.

Each monitoring well should consist of two or more 2-inch piezometers, each separately isolated from the others by well seals. Each piezometer should be equipped with dedicated sampling equipment similar to the LSCE 200 monitoring device shown on Figures 12A and 12B. The equipment should be capable of:

-purging 5 to 10 casing volumes of water from the piezometer well.

-monitoring the piezometric water level of the aquifer being studied

-extracting water samples for qualitative analysis.

The preliminary site investigation program should consist of the following.

A. Monitoring well construction

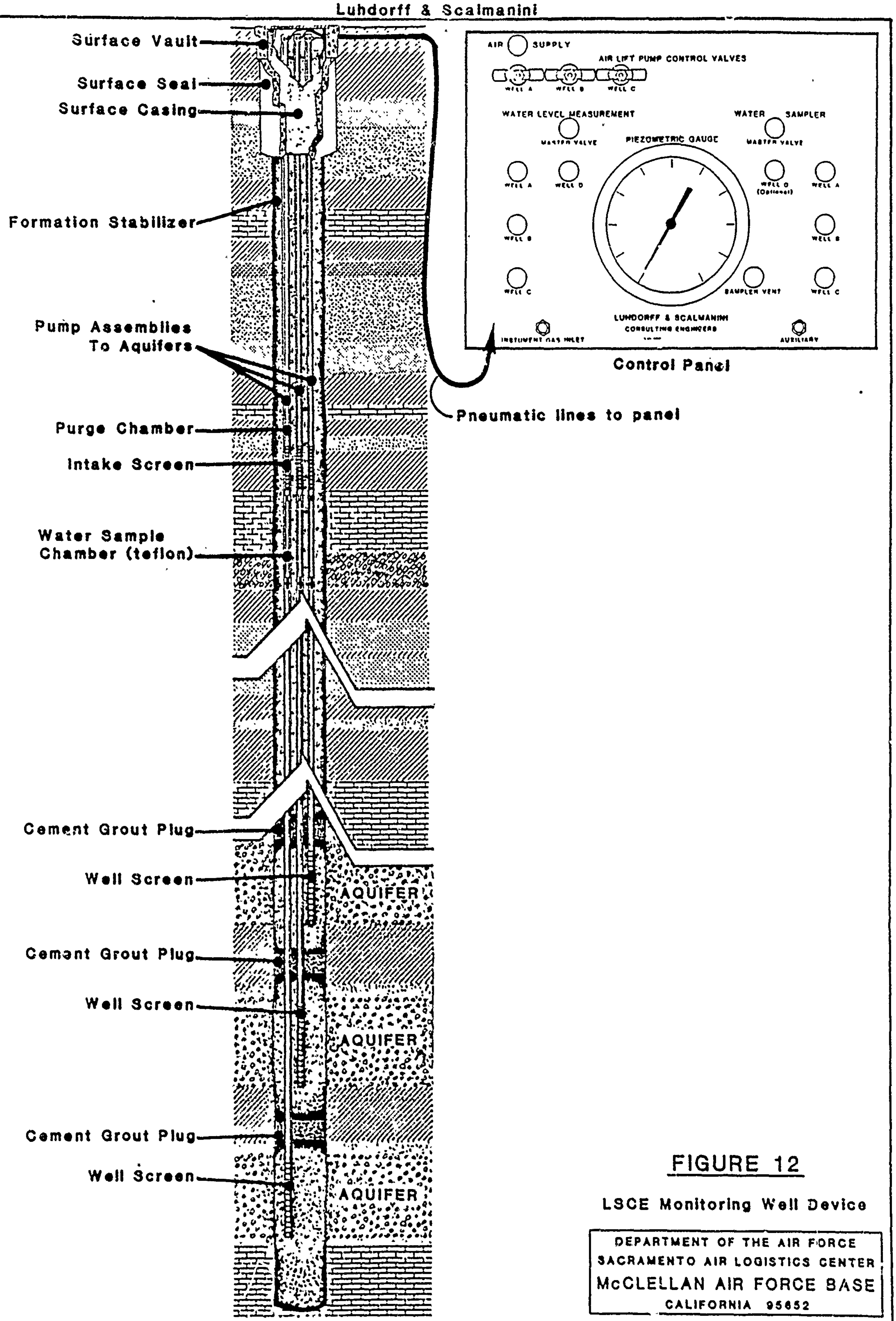

FIGURE 12

LSCE Monitoring Well Device

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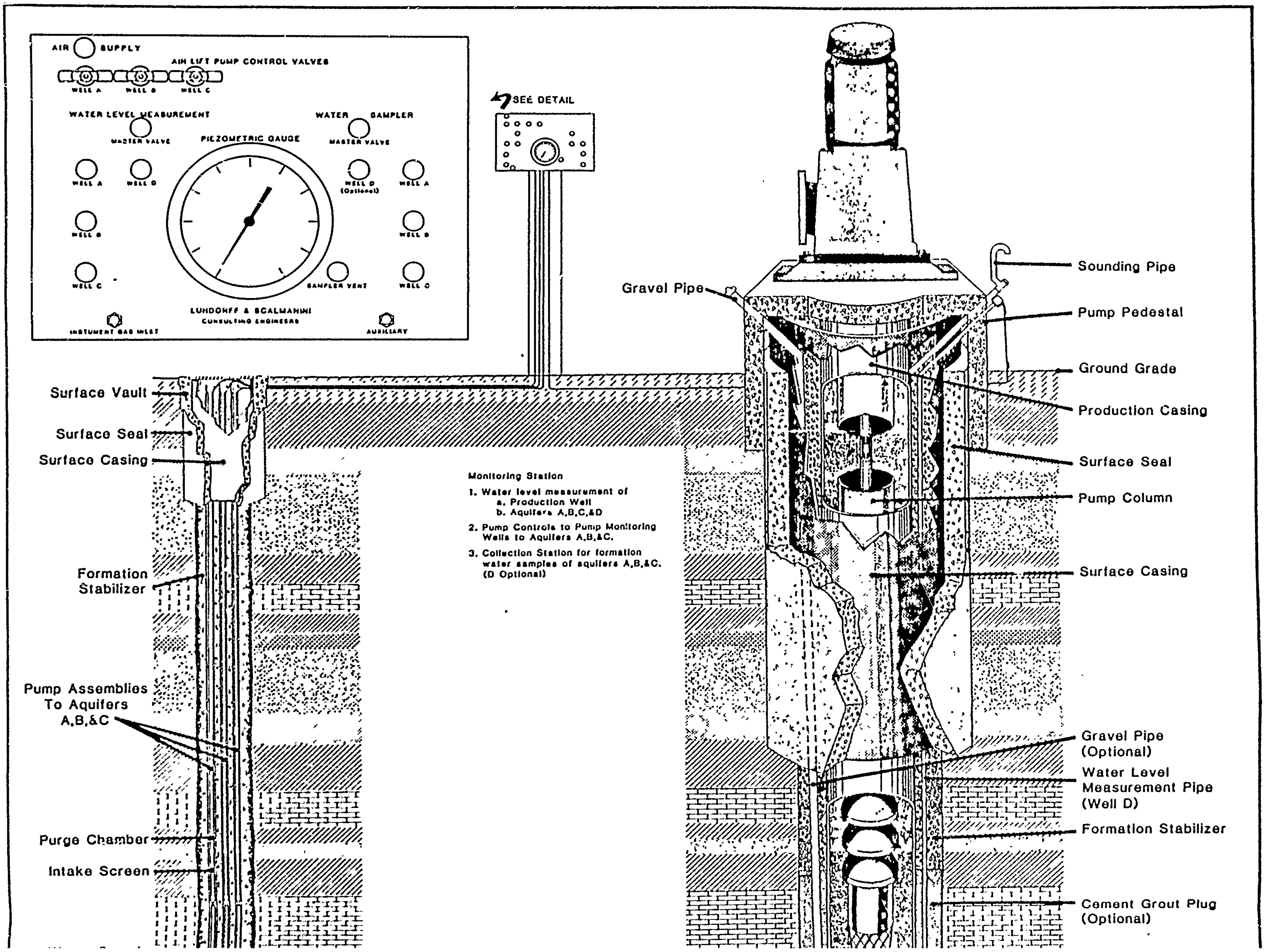

AIR SUPPLY
AIR LIFT PUMP CONTROL VALVES
WELL A
WELL B
WELL C
WATER LEVEL MEASUREMENT
MASTER VALVE
PIEZOMETRIC GAUGE
WATER SAMPLER
MASTER VALVE
WELL D (Optional)
SAMPLER VENT
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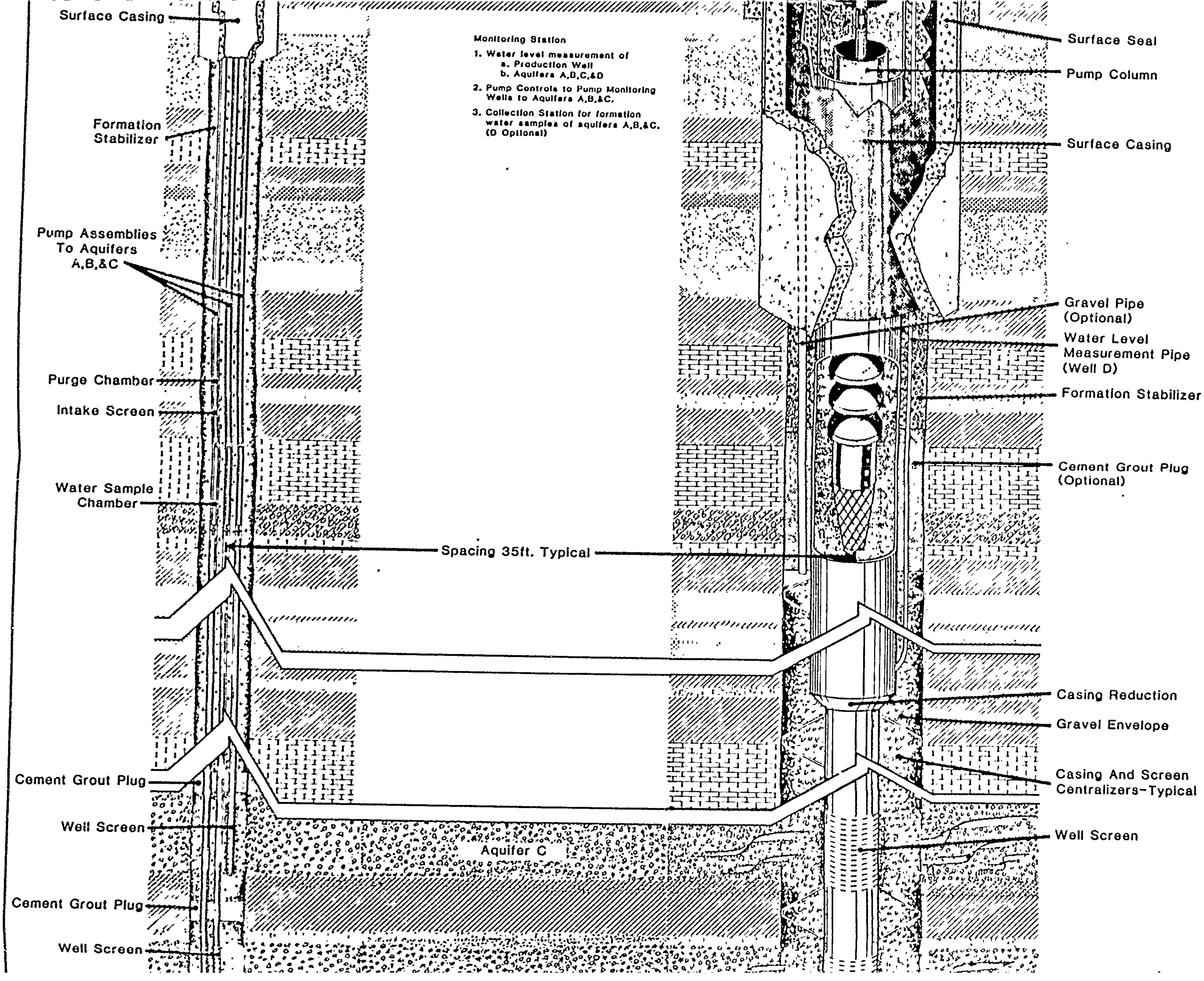
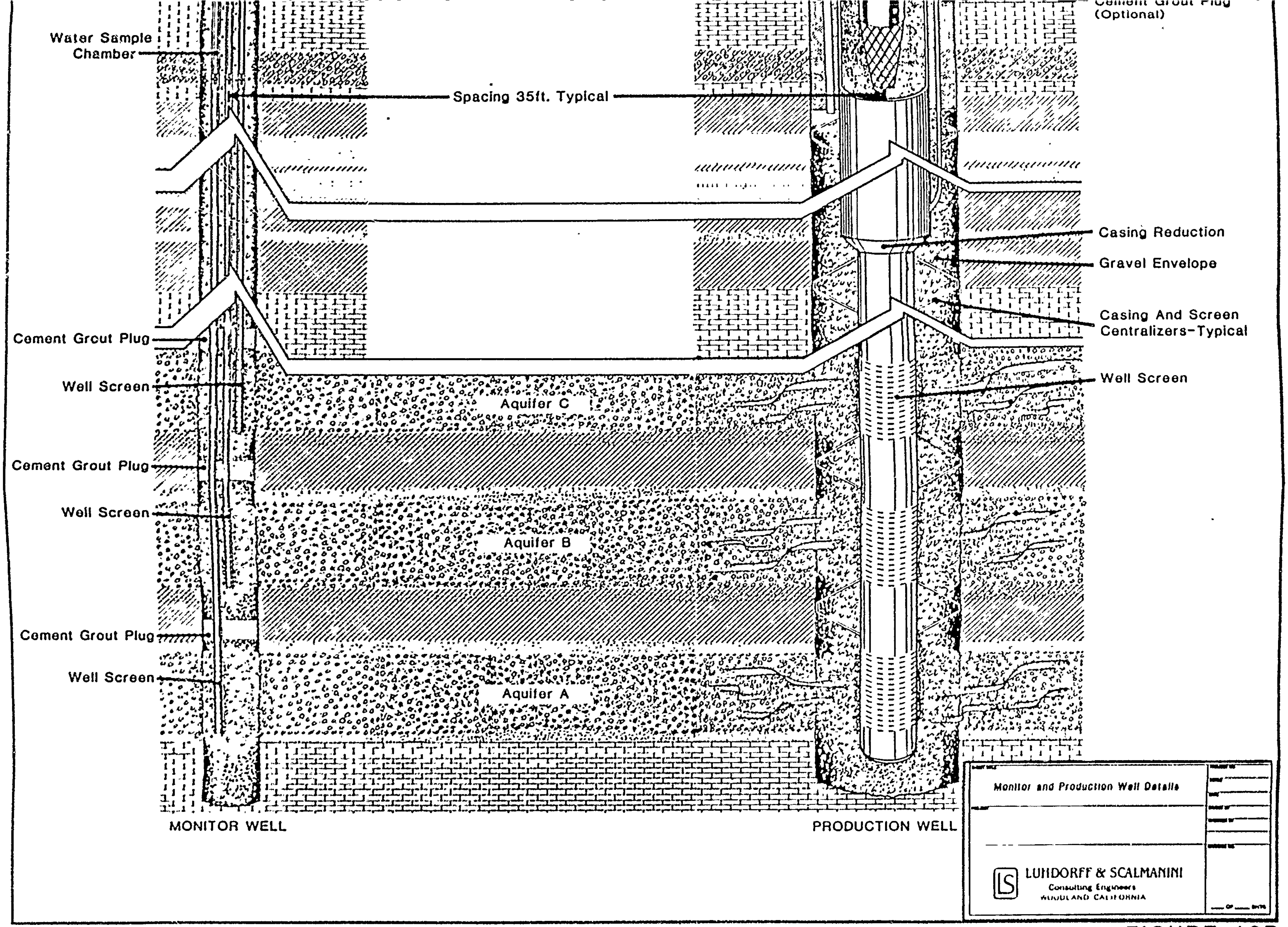
CONSULTING ENGINEERS
AUXILIARY
SEE DETAIL
Gravel Pipe
Sounding Pipe
Pump Pedestal
Ground Grade
Production Casing
Surface Seal
Pump Column
Surface Casing
Gravel Pipe (Optional)
Water Level Measurement Pipe (Well D)
Formation Stabilizer
Cement Grout Plug (Optional)
Surface Vault
Surface Seal
Surface Casing
Formation Stabilizer
Pump Assemblies To Aquifers A,B,&C
Purge Chamber
Intake Screen
Monitoring Station
1. Water level measurement of
a. Production Well
b. Aquifers A,B,C,&D
2. Pump Controls to Pump Monitoring Wells to Aquifers A,B,&C.
3. Collection Station for formation water samples of aquifers A,B,&C. (D Optional)



Surface Casing
Formation Stabilizer
Pump Assemblies To Aquifers A,B,&C
Purge Chamber
Intake Screen
Water Sample Chamber
Cement Grout Plug
Well Screen
Cement Grout Plug
Well Screen
Monitoring Station
1. Water level measurement of
a. Production Well
b. Aquifers A,B,C,&D
2. Pump Controls to Pump Monitoring Wells to Aquifers A,B,&C.
3. Collection Station for formation water samples of aquifers A,B,&C. (D Optional)
Spacing 35ft. Typical
Aquifer C
Surface Seal
Pump Column
Surface Casing
Gravel Pipe (Optional)
Water Level Measurement Pipe (Well D)
Formation Stabilizer
Cement Grout Plug (Optional)
Casing Reduction
Gravel Envelope
Casing And Screen Centralizers-Typical
Well Screen



Cement Grout Plug
(Optional)
Water Sample Chamber
Spacing 35ft. Typical
Casing Reduction
Gravel Envelope
Casing And Screen Centralizers-Typical
Cement Grout Plug
Well Screen
Cement Grout Plug
Well Screen
Cement Grout Plug
Well Screen
Well Screen
Aquifer C
Aquifer B
Aquifer A
MONITOR WELL
PRODUCTION WELL
Monitor and Production Well Details
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Consulting Engineers
WOODLAND CALIFORNIA

FIGURE 12B

1. Determine lithology from drill cutting samples and geophysical logs.

2. Select aquifers to be monitored for piezometric heads and water quality and determine the potential location of the production well seal.

3. Complete monitoring well construction and develop each piezometer.

4. Install the dedicated sampling equipment.

B. Analysis of the communication between aquifers via the gravel pack of Base production wells

1. Each installed Base well pump should be run and the following tests conducted.

a. Pump performance test to evaluate the overall plant efficiency of the installed pumping equipment. Comparisons of actual operating performance to that of the pump performance curve for the pump unit installed will provide the information necessary to perform maintenance on the equipment if and when it is removed from the well for well seal installation.

b. During the pump testing, water levels in each of the piezometers installed should be monitored to determine if the impact of pumping of the production well is reflected in the shallow aquifers. If no changes in the piezometric levels are

observed in the shallow aquifer being monitored, it may be reasonably concluded that the aquifer being monitored does not serve as a source for contaminant entry into the well through the gravel pack. This condition very likely occurs in many of the Base production wells because of their method of construction. Direct rotary circulation drilling techniques used by many of the water well drilling contractors over the past forty years included the setting of well casing and installation of gravel pack materials into bore holes which contained highly viscous drilling muds. Well development by the contractors removed the drilling fluids opposite the screened intervals of the well but generally did not remove the drilling muds from the gravel packing material adjacent to the blank casing above the static water levels in the well. These drilling fluids consisted primarily of bentonite clays, a material highly suitable for well sealing. If not intentionally removed during the initial well development by a procedure requiring the recirculation of water down the gravel envelope during the initial test pumping of the well, a practice few contractors followed, the production well may already be adequately sealed.

If, on the other hand, piezometric levels in the monitoring well fall during the pumping of the production well, the aquifer being monitored will be producing water down the gravel pack and into the production well.

These observations are very significant in determining the

hydraulic connection between the upper and lower aquifers via the bore hole of the production well. The Phase II Confirmation Study provided adequate data to support the conclusions that the shallow aquifers have higher static water levels than the lower aquifers being used for water development. Monitoring only the static piezometric water levels would suggest that vertical communication of the shallow aquifers to the lower aquifers is occuring. Pumping of the production well, allowing dynamic fluid levels to be read, will qualify each well's need for sealing.

C. Water Quality Sampling

Water quality sampling should be performed during the pumping operations from each of the installed piezometers and the production wells. Water quality sampling should be conducted after a sufficient pumping time has elapsed to allow the water held in storage within the aquifers between the production well and the monitoring well to have been discharged from the well. Sampling from all piezometers which are demonstrated to be hydraulically connected to a production well will provide an understanding of the origin of the constituents which comprise the water produced from the production well.

D. Well Efficiency Analysis

During pump testing, step drawdown and constant rate pumping tests should be conducted to evaluate the production well's efficiency. Such data would be evaluated with other data collected to determine the need for well rehabilition, a maintenance consideration if the pump is ultimately removed from the well for

sealing.

E. Summary of Data Evaluation

Evaluation of the data gathered during the site preliminary site investigation would determine the following:

1. wells requiring sealing.
2. pumps requiring rehabilitation or modifications for increased plant efficiency.
3. wells requiring rehabilitation to improve their hydraulic efficiency.
4. water quality of selected aquifers.
5. identify aquifers containing contaminent plumes adjacent to the production wells.

The instal`ation of the monitoring wells would provide additional data essential in monitoring aquifer characteristics in the future. The dedicated monitoring devices would provide continuing data on the water quality of each of the aquifers, changes in their hydraulic gradients with time and immediate source location of contaminents should they be detected in a Base production well in future years.

Recommended Well Sealing Methcdology

In the preceeding discussion, the need to identify wells that require sealing of their gravel pack to isolate specific aquifers has been addressed. The following sealing procedures assume that the recommended site investigation

has been conducted, the aquifers identified, and the sealing interval selected for each production well.

At McClellan, the vast majority of the Base production wells are housed in concrete buildings having floor elevations which vary from ground level to depths of several feet below the ground level. Access to each pump for maintenance purposes is through roof openings installed for this purpose in each building. All activities of pump removal and well sealing will be performed through this opening.

The procedure recommended for the sealing of Base production wells is to install a cement slurry in the gravel envelope of the selected wells using the secondary remedial cementing procedure known as the Bradenhead method. References will be made to specific industry equipment that would be employed in the well sealing operation. When applicable, details of such equipment are presented in Appendix E. To implement this program, the following steps should be taken.

1. Removal of Pumping Equipment.

It will be necessary to remove from the well the deepwell turbine pump equipment installed. A truck mounted crane having a minimum boom height of 40 feet above the building roof to be accessed and a working load capacity of 30,000 pounds when positioned over the access hole, shall be specified for use on the project. The turbine pump shall be removed from the well using conventional pump pulling procedures. Weight of the pump during removal, shall be supported using casing elevator clamps which shall rest on the well head foundation during column

section removal. The pump shall be directly loaded on a trailer and taken to an assigned area of the Base for storage during well repairs. Upon its removal, the Project Engineer should inspect the pump in order to establish a list of recommended or necessary repairs or maintenance which should be submitted to Base personnel for review and processing.

2. Preparation of the Well for Sealing

The internal well structure should be inspected prior to commencing the sealing operations. A down-hole television survey of the well should be conducted to examine the casing integrity of the well and to determine the need for well maintenance in support of the well efficiency tests conducted during the site investigation. Deficiencies noted should be evaluated by the Project Engineer and Base Officials, and a determination made whether or not to proceed with the sealing operation.

Assuming that well sealing is to be performed, a tremie pipe of at least four inch nominal diameter should be installed in the well, supported during its installation on the well foundation. The tremie pipe should be installed to within 20 feet of the bottom of the well. Selected uniform well rounded, washed gravel packing material, comparable in aggregate size to Monterey Sand Company's 6-12 pack should be installed through the tremie pipe from the bottom of the casing to a depth ten feet below the selected depth of sealing. The gravel tremie pipe shall be removed from the well in 20 to 30 foot sections as gravel is placed in the well. The tremie pipe should then be raised five feet above the pack. Two feet of fine sand should be placed on top of the gravel pack, followed by a one foot cap of cement. The cement composition shall be as defined later in

this chapter. The tremie should then be removed from the well. The cement cap should be allowed to remain in the well for a period of at least 24 hours before additional work is performed in the well.

At the surface, the well casing should be exposed for welding. A steel casing should be installed on the existing casing and run a minimum of one foot above the building's access hole. On the top of the casing a discharge head shall be installed to permit the pressurizing of the casing.

The casing should then be filled with water to determine if casing leaks exist in the well.

3. Perforating Well Casing

Perforation of the w' ı casing opposite the zone to be sealed should be performed using conventional oilfield gun perforating equipment. For the casing diameters installed at McClellan, the perforating device selected would be a hollow carrier casing gun as supplied by well industry wire line service companies. In normal oilfield practice, four to six holes are adequate for formation sealing. At McClellan, two rows of four shots would be installed over a two foot interval opposite the center of the selected zone for sealing.

After casing perforation, the casing should be filled with water and an injection test conducted to determine the formation's ability to receive fluid at selected pressures and injection rates. The values obtained would determine the pressure requirements for slurry injection.

4. Installing Cement Slurry

Ideal squeeze cement slurry is designed to permit adequate thickening time, yet produce sufficient compressive strength with a minimum waiting-on-cement time. Most slurries are designed with neat or retarded cements. Additives, when added to the slurry, help prevent rapid fluid loss (dehydration) under high pressure squeeze conditions. In establishing the recommendations for slurries to apply at McClellan, Halliburton Company's laboratory evaluated several slurries and conducted tests to simulate the expected McClellan sealing requirements. The test results and reports are contained in Appendix E.

A cementing string should be installed in the well opposite the area to be sealed, the selected Class G cement with the selected Halad additive then pumped into the well casing opposite the installed perforations. The amount of cement pumped into the casing annulus is based upon the volume necessary to displace formation waters contained in the gravel pack of the well over an approximate ten foot interval assuming a formation porosity of thirty percent. After cement placement, the cementing string is removed from the casing and the Bradenhead assembly installed at the surface. The cement is then displaced into the annulus between the casing and borehole by pumping water into the casing at the preselected squeeze pressures and selected fluid volume. Figure 13 illustrates the steps taken to effect the placement of cement.

The well would then be allowed to remain at rest for a period of twenty-four hours.

5. Equipment Requirements

A drill string assembly consisting of a stabilized blade bit similar to a Hughes "Blue Demon", 6000 pounds of drill collars, 4 1/2 inch pipe, an airchamber and an external air line is next installed into the well casing to drill through the residual cement slurry. Figure 14 illustrates the complete drilling assembly recommended to be employed when using a conventional truck crane.

Operation of the system utilizes the principles of reverse circulation rotary drilling to remove the cement plug and sand pack from within the well casing.

Two devices which permit the mobile crane to function as a drilling unit are the Bowen Model S-2.5 85 ton power swivel and the Howard Turner rotary rotation head. The Bowen air operated power swivel provides a variable rotation speed to the drill pipe assembly to drill through the installed cement plug and to subsequently agitate the supporting sand pack installed in the casing. The Howard Turner rotating head allows the external line to rotate with the drill pipe to become a reverse circulation piping assembly for the removal of material from the well. The material from the well is air lifted up the drill pipe, through the Bowen swivel and discharged into a receiving truck for reuse on each well installation designated for sealing. Coincident with the removal of the sand will be the pumping of water from the well. An estimated 100 to 300 gallons per minute may be produced from the well during sand removal. To effect proper handling of the waste water, a water quality analysis program would be established to test the water produced from the well to determine the proper disposal practices for each well. The disposal of the water pumped will be

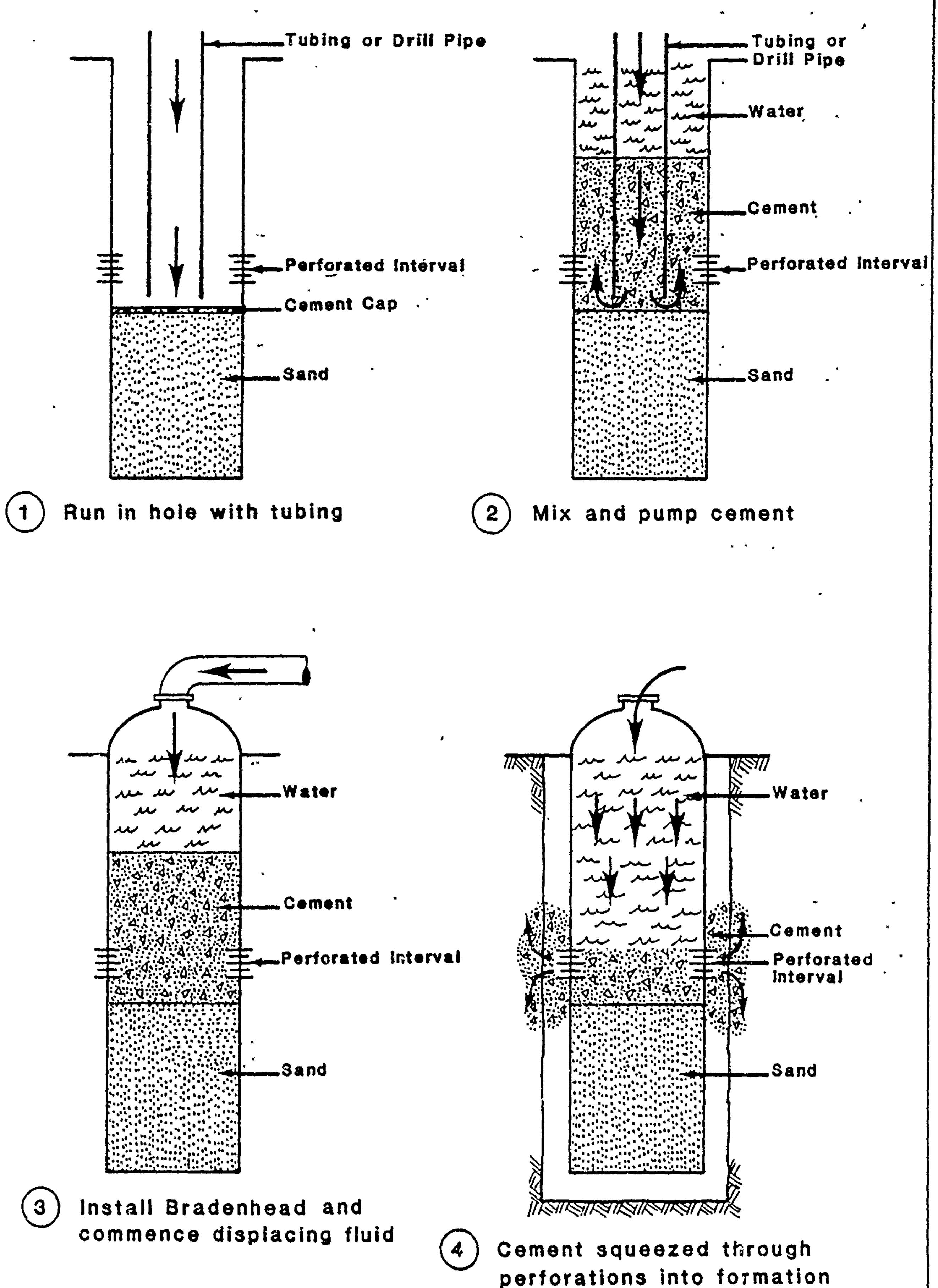

FIGURE 13
Cementing Utilizing the
Bradenhead Squeeze Technique

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McCLELLAN AIR FORCE BASE
CALIFORNIA 95652

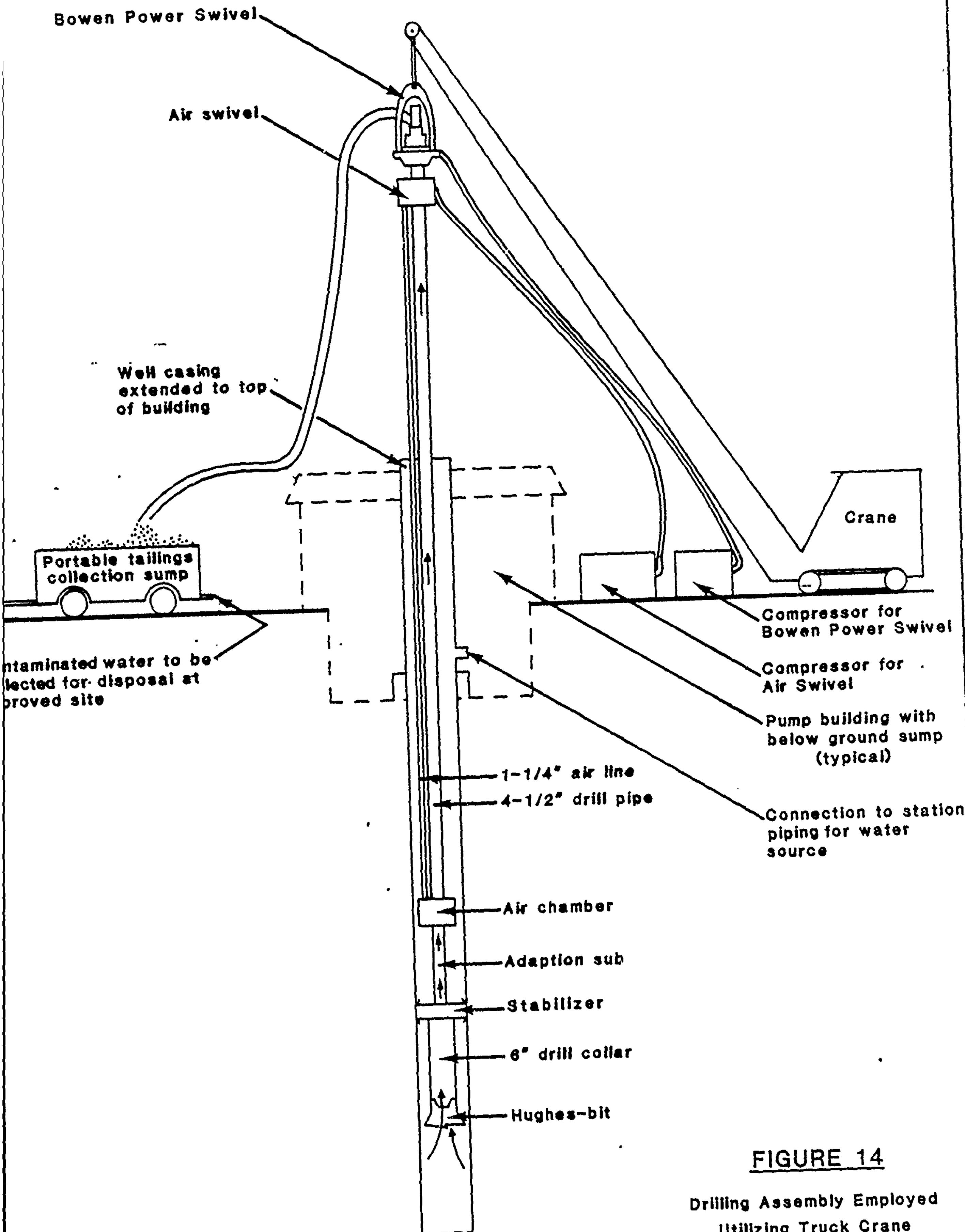


FIGURE 14

Drilling Assembly Employed Utilizing Truck Crane

DEPARTMENT OF THE AIR FORCE
SACRAMENTO AIR LOGISTICS CENTER
McCLELLAN AIR FORCE BASE
CALIFORNIA 95652

accomplished through the surface drainage facilities installed on the Base if the water is not contaminated. If contaminated, the pumped water would be collected and tanked to a designated disposal site. Water for drilling will be taken from McClellan's existing distribution system.

6. Inspection of the Well

Upon removal of the sand pack installed in the well, the well casing shall be inspected using down-the-hole television equipment. The casing assembly at the point of seal placement shall be additionally tested by conducting a caliber survey to measure the inside diameter of the casing. The allowable diameter of casing with the remaining cement wall shall be within one-half inch of its original diameter. A casing cement bond log will be conducted within the casing assembly to determine the uniformity of the cement placement outside the well.

7. Turbine Pump Facilities and Repair

The initial test pumping of the production well allowed for the examination of the efficiency of each production well and pump. If a production well is designated to receive a seal, the turbine pump when removed from the well should be examined for the normal wear of its operating components and repairs effected prior to its reinstallation. A history of the repairs previously performed on each Base pump unit has been developed from the Base maintenance records and is contained in Appendix D. The repaired turbine pump should be reinstalled in the production well following the acceptance of the well inspection and caliper surveys.

8. Testing of the Well

Production pump and well testing are next performed to verify the acceptable operation of the turbine pump and to determine the effectiveness of the sealing operations. The probability of success of the effective placement of the seal by the methods proposed is extremely high. The cementing techniques to be employed are conventional procedures routinely employed in the oil, gas and water well industries. Unknown at the time of seal placement is the extent of the confining clay member which is to serve as the barrier to the vertical downward movement of contaminants within the gravel envelope of the well. Pumping of the well with the concurrent monitoring of the shallow aquifers isolated in the constructed monitoring well will determine, by the hydraulic gradients developed, the success of the seal placement and the integrity of the confining member. Calculations of the diameter of the expanding cone of depression of the pumped well with time, with the extended monitoring of the gradients developed within the shallow piezometers, will provide an increased understanding to the regional hydrology underlying the Base.

WELLS TO BE SEALED

1. Base Production Wells

Thirteen wells were identified in Chapter II as being either operational, on standby, or out of service due to TCE contamination. The balance of historically used wells on the Base has been abandoned or destroyed. The latter grouping, those abandoned or destroyed, offer little potential to the hazards of contaminant transport to the lower aquifers underlying the Base. While the

methods of their abandonment or destruction are not known, it may be assumed that they were removed from service using the traditional practice of filling the casing with sand or gravel, capped over with top soil. Discovery and proper destruction of the lost wells is, for practical purposes, not feasible. While this fact will, to some, be of concern, it should be recognized that contaminant transport down the gravel envelope occurs principally from the large localized gradients which occur during pumping. Once the contaminant does move to the lower aquifers, it is subject to further migration by the gradients occuring within that aquifer. As such, the movement within the lower aquifer from point to point is extremely slow. To fully evaluate the potential for the destroyed or abandoned wells to serve as conduits for contaminant movement would require an evaluation of the aquifer characteristics of those formations formerly used by each of the wells. Localized gradients created by existing pumped wells near each of the abandoned wells will increase the potential for downward movement of the contaminants. As such, each of the wells should be reevaluated when such data becomes available from such studies as recommended in the suggested Preliminary Site Investigation. From the data presently available, none of the abandoned wells is considered to require sealing.

Of the production wells is service or on standby, two wells (No. 17 and 28) are known to have been constructed by the cable tool drilling method and have no gravel packs. As such, they require no sealing. The balance of the wells either have known gravel packs, or by the limited construction data available, are believed to have a gravel pack surrounding the production casing. It is recommended that these remaining wells be further investigated as discussed under "preliminary site investigation" to determine if their gravel envelopes are serving as conduits for contaminant movement from the shallow to the deep

aquifers. These wells include well numbers 1, 2, 12, and 18, all presently out of service due to the presence of TCE; well numbers 8, 10, and 13, currently operational and in service; and wells 4, 11, and 20, operational but on standby. Well number 29 has a history on excessive sand production and is being considered for destruction by the Base Water Department.

Consideration for the abandonment of well number 2, in lieu of sealing, has been suggested in previous investigations. Engineering Science, in their Phase II Confirmation Study, recommended that the well be abandoned because its upper perforated section (from 100 to 112 feet) exposes the well to the shallow aquifers suspected contaminated with TCE. This section can be sealed and removed from production in the well by the sealing methods proposed herein. The well therefore has been included in the proposed list of wells to be sealed. LSCE does not recommend any production well be destroyed at this time because of the presence of VOC's at McClellan.

2. Base Monitoring Wells

Wells constructed using PVC casing cannot be sealed using the methods prescribed for the production wells. The practical inability to alter the casing material without causing its structural failure, the limited working area inside the casing and foremost, the cost of replacing the well versus its repair, causes its alteration to be economically not justified. Monitoring wells which would be candidates for sealing would more practically be considered wells requiring abandonment.

Of the numerous monitoring wells constructed, the initial nine constructed

pose the greatest hazard for allowing the vertical transport of contaminants.

Well number 1 was accidently filled during an attempt to reduce its depth to 120 feet and is no longer available for use. Well number 2 has been filled with sealing material to the depth of 120 feet. Wells 3 and 4 are as originally constructed but have not been subject to contamination.

The sealing practice used for wells 1 and 2 would have provided adequate sealing of the gravel envelop below depths of 120 feet. Sealing at higher elevations in the well does not provide any added degree of protection to McClellan's groundwater supplies; therefore, no further action seems warranted. Wells 3 and 4 were installed to monitor contaminant movement. Until contaminants are discovered within the wells, they serve no detrimental purpose as constructed. If contaminants are found in the wells, they should be initially grouted up to depths of the shallow aquifers then used for monitoring purposes.

Monitoring wells MW5 through MW9, because of their depth and method of completion, provide avenues for contaminant movement in their annulus between the casing and the borehole, from the shallow to the deeper aquifers underlying the Base. If contaminants are discovered in these wells, they too should be destroyed as noted above.

Recommendations for Sealing by Engineering Science

Engineering Science, in their Phase II Confirmation Study summary, proposed several steps to be taken in well sealing and abandonment. Each recommendation is restated below with comments by LSCE on their suggested methodology.

1. That "Base Production Wells known to have gravel-packed casings be sealed by slant drilling at depths from 75 feet to 120 feet. This would include Base Wells 1, 7, 8, 18, 20, and 29."

The use of "slant drilling" techniques to intercept the gravel envelope of Base production wells is not practical. The drilling contractor would be required to intercept a gravel envelope which at its maximum thickness is 6 inches wide at a depth 75 to 100 below ground with the drilling rig located a minimum of twenty feet from the production well. The ability to determine the gravel pack material from other drill cuttings would be difficult if the contractor was fortunate enough to encounter the pack. The drilling procedure would not provide the ability to control the necessary pressure grouting within a confining section of the borehole. Concern must be raised for the potential hazards of damaging the casing, should it be encountered during drilling.

Well number 7 is known to be abandoned. While its gravel pack was not destroyed during the earlier destruction of the well, it is not known if the pack offers a conduit for contaminant movement to the lower aquifers. Because of the limited total area of the gravel pack and the former well's distance from other existing Base supply wells, the local differential pressure gradient between the shallow and deep aquifers experienced at the site would not allow significant groundwater movement to occur. Well number 7 therefore becomes no more significant in the overall consideration for sealing than any of the other nine abandoned wells on the Base.

2. "For Base wells 10, 11, 12, and 13, for which no well logs exist, video

cameras should be lowered into the wells to ascertain whether they were constructed by cable tool methods. If they were constructed by cable tool, there would be no gravel packs and the wells would require no further corrective measures. If the wells did have gravel packs, sealing would be required by slant drilling."

The use of video equipment cannot be used to determine the method of well construction. While certain construction techniques, such as the use of a mills-knife for perforating casing, were more commonly used in cable tool construction, the tool was also applied in direct rotary drilling completions. Numerous other duplications of equipment and techniques could be cited to support the fact that video inspection will not identify the original method of construction.

LSCE agrees with the Engineering Science conclusion that cable tool construction provided no gravel pack and wells constructed by this method require no sealing.

3. "Base Well 2, with perforations starting at 100 feet, is located in an inaccessible well house. The well house should be removed and the well abandoned by pressure grouting the gravel pack through existing perforations."

Well number 2 can be sealed in the area of the upper perforated section and returned to service as previously discussed in this report.

4. "Base monitoring wells, 1, 2, 3, and 4 should be abandoned by sealing the gravel pack."

It is the opinion of LSCE that wells number 1 and 2 are adequately sealed, and that wells number 3 and 4 can remain in service as monitoring wells until contaminants are found. When contaminants are discovered, the wells should be reduced in depth and used as shallow monitoring wells. Engineering Science did not make any recommendations concerning the sealing of monitoring wells 5 through 9. As previously cited, LSCE has recommended that these wells be destroyed or reduced in depth if contaminants are found in them.

CHAPTER 4

BASE MAINTENANCE PROGRAM AND RECORD KEEPING

CHAPTER 4

BASE MAINTENANCE PROGRAM AND RECORD KEEPING

McClellan Air Force Base operates an effective water well maintenance program under the supervision of the Water Department, a division of the Base Civil Engineering section. The Water Department has sole responsibility for the maintenance of each well and pump operated by McClellan both on and off the Base.

To maintain records of each installation's performance and repair, a series of reports is prepared for daily and monthly operations. Each may be described as follows:

AF Form 996 - Well Maintenance

Recorded on this form is a record of all major repairs performed on the subject well or pump.

AF Form 997 - Daily Well Activity

Each production well is inspected daily on the Base. Readings are taken and recorded on the subject form of the following data:

a. daily water production - cumulative totals of the gallons of water pumped are read from the totalizing flow meter installed on the discharge of the pump.

b. totalizing watt-hour meter - the power consumed during the period between readings is obtained from a totalizing watt-hour meter.

c. water level - a hand operated air pump is used to determine the static or pumping water level in the well at the time of inspection.

d. weight of chlorine - chlorine tank weight is recorded to determine the amount of chlorine used for water disinfection.

AF Form 1461 - Monthly Operating Report

This form summarizes monthly, the daily reports of the well and pump performance as reported on AF Form 997. Additionally, the report contains a summation of AF Form 998, the pumping station log used to record non-well related pump performance installed at the station such as booster pumps.

Base personnel additionally prepare a time series graphical representation of the average monthly water levels, both static and pumping, which have been recorded. The graphical representations are available for most well installations for the past twenty years of operation.

Not present in these forms was a graphical representation of the well's specific capacity, the discharge capacity (in gallons per minute) divided by the drawdown from the static water level to the pumping level (in feet). This information is extremely useful in observing changes in the performance of a well, an occurrence which often reflects a change in the efficiency of a well.

Reductions in specific capacity often alert the well user to the need for well repair or well rehabilitation.

LSCE has developed from the available data, curves which reflect the historical specific capacity for the existing production wells. These curves are presented in Appendix D. Review of the curves note the continued decline of the specific capacity in two wells, 8 and 12. Well number 12 should be carefully examined for possible rehabilitation if, during the recommended preliminary site investigation (Chapter 3), it is considered necessary to effect well sealing. Well number 8 is a cable tool constructed well and will not be sealed. Well rehabilitation should be considered if, in the future, repairs are performed on the pumping equipment of well number 8.

Records of well maintenance and pump repairs have been summarized for each of the operational well installations at McClellan. These data sheets should be reviewed for background information on those wells requiring the installation of well seals as determined from the recommended preliminary site investigation. The data sheets contained after the concluding remarks of this chapter list the historical well and pump repairs performed on the Base operational wells.

Chapter 2 discussed the low production obtained from monitoring wells constructed during the Phase II Confirmation Study and suggested that the low flow rates may be due to low well efficiency. If the wells have reduced efficiency due to improper or insufficient well development, such efficiency may be increased through well rehabilitation. If successful, the wells could be pumped at higher capacities which would permit a re-examination of the aquifer characteristics developed during the Phase II investigation. The rehabilitation

procedures should include the use of chemicals to remove the drilling fluids used during construction, well swabbing and bailing of the well and re-pumping. Definitive programs for well rehabilitation are beyond the scope of this report but such work should be made a part of the maintenance program for wells at McClellan.

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

Well No.: 1 Location: Building 231

Present Status: Out of service due to contamination

Driller: F.H. Eaton

Method of Construction: Rotary Date of Construction: April 1937

Electric Log: Not available Lithology: Air Force dwg. no. 6870-208 and USGS geologist report

Conductor Pipe Diameter: 24 inch Depth: 39 feet

Method of Seal: Sealing clay/neat cement Depth: 0-32 feet/32-39 feet

Blank Casing Type: 12 inch steel to 400 feet

Perforated Section
Type: 6 inch long by 1/4 inch milled slots; 6 perforations per row per foot
Schedule: 162-174 ft.; 233-236 ft.; 247-252 ft.; 263-266 ft.; 276-294 ft.; 338-357 ft.; 378-396 ft.

Gravel Pack Type: 6 inches of 1/4 to 3/8 inch Depth: 0-400 feet

Maintenance Records: Air Force Form 996 - Sheets 1 thru 4 inclusive

Photographic Records: Feb. 1969 - Laval Photosurvey; 1981 - Well Tech video survey

Water Level and Production Records: Air Force Form 1461

REMARKS: None

MAJOR REPAIRS OR ALTERATIONS:
1) 9/53 - Sand separator installed.
2) 3/56 - Well bailed;pump rebuilt; set to 110 ft.
3) 7/59 - Auxillary engine rebuilt.
4) 2/69 - Pump rebuilt; set to 130 ft.
5) 12/76 - Pump rebuilt; set to 160 ft.
6) 2/78 - New auxillary engine.
7) 1/79 - New sand separator.
8) 11/79 - Taken out of service; TCE.
9) 2/80 - Put back into service; low TCE.
10) 3/80 - Taken out of service; TCE.
11) 5/81 - Video scan of well.

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

Well No.: 2 Location: Building 232

Present Status: Out of service due to contamination

Driller: F.H. Eaton

Method of Construction: Rotary Date of Construction: April 1937

Electric Log: Not Available Lithology: Air Force dwg. no. 6870-208 and USGS Field Report

Conductor Pipe Diameter: 24 inch Depth: 40 feet

Method of Seal: Sealing clay/neat cement Depth: 0-33 ft./33-40 ft.

Blank Casing Type: 12 inch steel to 298 feet

Perforated Section
Type: 6 inch long by 1/4 inch milled slots; 6 perforations per row per foot
Schedule: 100-112 ft.; 141-158 ft.; 180-197 ft.; 282-296 ft.

Gravel Pack Type: 6 inches of 1/4 to 3/8 inch Depth: 0-298 feet

Maintenance Records: Air Force Form 996 - Sheets 1 and 2

Photographic Records: May 1970 - Laval Photosurvey

Water Level and Production Records: Air Force Form 1461

REMARKS:
1) Original 10 inch test bore depth was 405 feet.

MAJOR REPAIRS OR ALTERATIONS:
1) 10/58 - Install new 30 HP pump; set to 110 ft.
2) 4/70 - Well bailed and caged; pump set to 152 ft.
3) 9/70 - Well throttled to 400 gpm due to air entrainment.
4) 1/71 - Well sonar jetted.
5) 2/79 - New sand separator.

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

Well No.: 3 Location: Building 663 area

Present Status: Abandoned or destroyed

Driller:

Method of Construction: Date of Construction:

Electric Log: Lithology:

Conductor Pipe Diameter: Depth:

Method of Seal: Depth:

Blank Casing Type:

Perforated Section
Type:
Schedule:

Gravel Pack Type: Depth:

Maintenance Records:

Photographic Records:

Water Level and Production Records:

REMARKS:
1) No records were available on this well. The well is reported to be an "old farm well existed prior to the McClellan Air Depot land acquisitions.

MAJOR REPAIRS OR ALTERATIONS:

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

Well No.: 4 Location: Winstead Atheletic Field

Present Status: Irrigation standby only

Driller: Not available

Method of Construction: Rotary Date of Construction: July 1941

Electric Log: Not available Lithology: Air Force dwg. no. 6870-247

Conductor Pipe Diameter: 24 inch Depth: 81 feet

Method of Seal: Not available Depth: Not available

Blank Casing Type: 12 inch steel to 382 feet

Perforated Section
Type: Not available
Schedule: 169-382 ft

Gravel Pack Type: Not available Depth: Not available

Maintenance Records: Air Force Form 996 - 1 sheet

Photographic Records: Not available

Water Level and Production Records: Not available

REMARKS:
1) This well was used for irrigation only, and was taken out of service due to poor performance - year unknown.

MAJOR REPAIRS OR ALTERATIONS: None noted.

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

Well No.: 5 Location: Old Garden Highway - "Old River Dock Well"

Present Status: In service

Driller:

Method of Construction: Date of Construction:

Electric Log: Lithology:

Conductor Pipe Diameter: Depth:

Method of Seal: Depth:

Blank Casing Type:

Perforated Section
Type:
Schedule:

Gravel Pack Type: Depth:

Maintenance Records:

Photographic Records:

Water Level and Production Records:

REMARKS:
1) This well is several miles south of the study area and therefore is beyond the scope of this study.

MAJOR REPAIRS OR ALTERATIONS:

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

Well No.: 6 Location: Building 714 area

Present Status: Abandoned or destroyed

Driller:

Method of Construction: Date of Construction:

Electric Log: Lithology:

Conductor Pipe Diameter: Depth:

Method of Seal: Depth:

Blank Casing Type:

Perforated Section
- Type:
- Schedule:

Gravel Pack Type: Depth:

Maintenance Records:

Photographic Records:

Water Level and Production Records:

REMARKS:
1) No records were available on this well. The well is reported to be an "old farm well existed prior to the McClellan Air Depot land acquisitions.

MAJOR REPAIRS OR ALTERATIONS:

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

Well No.: 7 Location: Building 489 area

Present Status: Destroyed

Driller: Aulman

Method of Construction: Rotary Date of Construction: July 1942

Electric Log: Not available Lithology: USGS geologist report and Air Force dwg. no. PU662

Conductor Pipe Diameter: 24 inch 10 gage steel double casing Depth: 50 feet

Method of Seal: Concrete Depth: 25 - 50 feet

Blank Casing Type: 12 inch 10 gage steel double casing to 398 feet

Perforated Section
Type: Not available
Schedule: 145-398 feet

Gravel Pack Type: 1/4 inch washed Depth: 0-398 feet

Maintenance Records: Not available

Photographic Records: January 1959 - Photosurvey

Water Level and Production Records: Not available

REMARKS: None

MAJOR REPAIRS OR ALTERATIONS:

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

Well No.: 8 Location: Building 91

Present Status: In service

Driller: Not available

Method of Construction: Rotary Date of Construction: July 1942

Electric Log: Not available Lithology: USGS geologist report and Air Force Dwg. No. PU 662

Conductor Pipe Diameter: 24 inch 10 gage steel double casing Depth: 43 feet

Method of Seal: Concrete Depth: 18 - 43 feet

Blank Casing Type: 12 inch 10 gage steel double casing set to approximately 625 feet

Perforated Section
 Type: Not available
 Schedule: Not available

Gravel Pack Type: None Depth:

Maintenance Records: Air Force Form 996 - Sheets 1 thru 4 inclusive

Photographic Records: Sept. 1966 - Laval Photosurvey; No date - Video survey

Water Level and Production Records: Air Force Form 1461

REMARKS: None

MAJOR REPAIRS OR ALTERATIONS:
1) 8/60 - Auxillary engine rebuilt.
2) 8/66 - Well photographed; Pump set to 140 feet.
3) 3/78 - New auxillary engine.
4) 8/78 - Rehabilitate well; Rebuild pump bowl; Pump set to 170 feet; New right angle gear installed.
5) 12/80 - Repair electric motor.

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

Well No.: 9   Location: Building 209 area

Present Status: Abandoned or destroyed

Driller: Western Well Drilling

Method of Construction: Rotary   Date of Construction: July 1953

Electric Log: July 1953 - Schlumberger   Lithology: Corp. of Engineers - 8 sheets

Conductor Pipe Diameter: 30 inch   Depth: Not available

Method of Seal: Grout   Depth: Not available

Blank Casing Type: 14 inch steel

Perforated Section
Type: Not available
Schedule: Not available

Gravel Pack Type: Not available   Depth: Not available

Maintenance Records: Not available

Photographic Records: Not available

Water Level and Production Records: Not available

REMARKS:
1) This well collapsed and was replaced by well 20.

MAJOR REPAIRS OR ALTERATIONS:

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

Well No.: 10 Location: Building 93

Present Status: In service

Driller: Not available

Method of Construction: Rotary Date of Construction: 1945

Electric Log: None available Lithology: Not available

Conductor Pipe Diameter: Not available Depth: Not available

Method of Seal: Not available Depth: Not available

Blank Casing Type: "14 inch steel with reduction to 12 inch steel at 144 feet

Perforated Section
Type: Not available
Schedule: 170-392 feet (determined from photosurvey)

Gravel Pack Type: Not available Depth: 400

Maintenance Records: Air Force Form 996 - Sheets 1 thru 4 inclusive

Photographic Records: June 1965 - Laval Photosurvey

Water Level and Production Records: Air Force Form 1461

REMARKS: None

MAJOR REPAIRS OR ALTERATIONS:
1) 11/59 - Overhaul auxillary engine.
2) 6/65 - Pulled pump for repairs; Pump set to 140 feet.
3) 2/79 - Install new sand separator.
4) 11/81 - Rehabilitate well.

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

Well No.: 11 Location: Building 2100

Present Status: In service - standby

Driller: Not available

Method of Construction: Rotary Date of Construction: 1945

Electric Log: None available Lithology: Not available

Conductor Pipe Diameter: Not available Depth: Not available

Method of Seal: Not available Depth: Not available

Blank Casing Type: 14 inch steel with a reduction to 12 inch steel at 140 feet (depth of string is 400 feet)

Perforated Section
Type: Milled slots
Schedule: 154-395? feet (photosurvey shows perforations to 346)

Gravel Pack Type: Not available Depth: Not available

Maintenance Records: Air Force Form 996 - Sheets 1 thru 3 inclusive

Photographic Records: May 1970 - Laval Photosurvey

Water Level and Production Records: Air Force Form 1461

REMARKS: None

MAJOR REPAIRS OR ALTERATIONS:
1) 1/58 - Replaced auxillary engine.
2) 11/59 - "Replaced auxillary engine.
3) 5/70 - Bail well; Pump set to 140 feet.
4) 7/76 - Replace right angle gear.

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

Well No.: 12 Location: Building 395

Present Status: Out of service due to contamination

Driller: Not available

Method of Construction: Rotary Date of Construction: Not available

Electric Log: Not available Lithology: Not available

Conductor Pipe Diameter: 24 inch Depth: Approximately 80 feet

Method of Seal: Not available Depth: Not available

Blank Casing Type: 12 inch steel to 390 feet

Perforated Section
Type: Not available
Schedule: 164-390 ft.

Gravel Pack Type: Not available Depth: Not available

Maintenance Records: Air Force Form 996 - Sheets 1 thru 4 inclusive

Photographic Records: March 1973 - Well Tech video survey

Water Level and Production Records: Air Force Form 1461

REMARKS: None

MAJOR REPAIRS OR ALTERATIONS:
1) 7/64 - Bail well; Rebuild pump; Pump set to 120 feet.
2) 3/73 - Rehabilitate well with sonar jetting; Bail well; Rebuild pump; Pump set to 140 feet; Repair motor.
3) 3/78 - Install new auxillary engine.
4) 1/79 - Install new sand separator.
5) 8/80 - Out of service due to contamination.
6) 8/81 - Remove pump from well.
7) 10/81 - Test well for TCE.

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

Well No.: 13 Location: Building 614

Present Status: In service

Driller: Not available

Method of Construction: Rotary Date of Construction: 1945

Electric Log: None available Lithology: Not available

Conductor Pipe Diameter: Not available Depth: Not available

Method of Seal: Not available Depth: Not available

Blank Casing Type: 14 inch steel with a reduction to 12 inch steel to 147 feet (total depth of casing is 391 feet)

Perforated Section
- Type: Not available
- Schedule: 178-391(?) ft.

Gravel Pack Type: Not available Depth: Not available

Maintenance Records: Air Force Form 996 - Sheets 1 thru 3 inclusive

Photographic Records: May 1971 - Well Tech Video

Water Level and Production Records: Air Force Form 1461

REMARKS: None

MAJOR REPAIRS OR ALTERATIONS:
1) 7/53 - Replace auxillary engine.
2) 4/71 - Repair pump.
3) 3/78 - New auxillary engine.
4) 1/82 - Pull pump; Rehabilitate well; Pump set to 160 feet.

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

Well No.: 14 Location: Unknown

Present Status:

Driller:

Method of Construction: Date of Construction:

Electric Log: Lithology:

Conductor Pipe Diameter: Depth:

Method of Seal: Depth:

Blank Casing Type:

Perforated Section
Type:
Schedule:

Gravel Pack Type: Depth:

Maintenance Records:

Photographic Records:

Water Level and Production Records:

REMARKS:
1) No records were available on this well.

MAJOR REPAIRS OR ALTERATIONS:

Well No.: 15 Location: Corner of Whitney and Eastern Ave. - Off base

Present Status: Abandoned or destroyed

Driller:

Method of Construction: Date of Construction:

Electric Log: Lithology:

Conductor Pipe Diameter: Depth:

Method of Seal: Depth:

Blank Casing Type:

Perforated Section
Type:
Schedule:

Gravel Pack Type: Depth:

Maintenance Records:

Photographic Records:

Water Level and Production Records:

REMARKS:
1) This well is several miles south of the study area and therefore is beyond the scope of this review.

MAJOR REPAIRS OR ALTERATIONS:

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

Well No.: 16 Location: Building 440 area

Present Status: Abandoned or destroyed

Driller:

Method of Construction: Date of Construction:

Electric Log: Lithology:

Conductor Pipe Diameter: Depth:

Method of Seal: Depth:

Blank Casing Type:

Perforated Section
Type:
Schedule:

Gravel Pack Type: Depth:

Maintenance Records:

Photographic Records:

Water Level and Production Records:

REMARKS:
1) This well reportedly served only building 440. No records were available.

MAJOR REPAIRS OR ALTERATIONS:

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

Well No.: 17 Location: Building 669

Present Status: In service

Driller: Not available

Method of Construction: Cable tool Date of Construction: Not available

Electric Log: Not available Lithology: Air Force dwg and USGS geologist report

Conductor Pipe Diameter: Not available Depth: Not available

Method of Seal: Not available Depth: Not available

Blank Casing Type: 16 inch steel to 353 feet

Perforated Section
Type: Not available
Schedule: 216-224 ft.; 286-294 ft.; 302-312 ft.

Gravel Pack Type: Not applicable Depth:

Maintenance Records: Air Force Form 996 - Sheets 1 thru 4 inclusive

Photographic Records: December 1971 - Well Tech Video Survey

Water Level and Production Records: Air Force Form 1461

REMARKS:
1) The original depth of the borehole was 930 feet.

MAJOR REPAIRS OR ALTERATIONS:
1) ?/56 - Removed two bowl units.
2) 12/56 - Auxillary gearhead and engine remeoved.
3) 8/60 - Install new pump and gearhead.
4) 10/71 - Wire brush well; Bail well; Photograph well; Pump set to 154 feet.

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

Well No.: 18 Location: Building 664

Present Status: Out of service due to contamination

Driller: D.B. Heard Co.

Method of Construction: Rotary Date of Construction: Feb. 1953

Electric Log: Oct. 1952 - Schlumberger Lithology: Air Force dwg. no. BU 2389

Conductor Pipe Diameter: 30 inch steel Depth: 50 feet

Method of Seal: Cement grout Depth: 50 feet

Blank Casing Type: 14 inch steel to 408 feet

Perforated Section
Type: 3/16 inch by 2 1/4 inch milled slots
Schedule: 169-185 ft.; 210-260 ft.; 304-349 ft.; 378-387 ft.

Gravel Pack Type: Not available Depth: 408 feet

Maintenance Records: Air Force Form 996 - Sheets 1 thru 3 inclusive

Photographic Records: May 1977 - Video survey; Feb. 1969 - Laval Photosurvey

Water Level and Production Records: Air Force Form 1461

REMARKS: None

MAJOR REPAIRS OR ALTERATIONS:
1) 1/69 - Install new pump, auxillary engine and sand separator.
2) 9/77 - Install new bowls.
3) 11/80 - Well found to be contaminated.
4) 6/81 - Out of service due to contamination.

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

Well No.: 19 Location: Building 663 area

Present Status: Abandoned or destroyed - Reported to have collapsed.

Driller: Not available

Method of Construction: Rotary Date of Construction: Nov. 1952

Electric Log: Nov. 1952 - Schlumberger Lithology: Air Force Drawing (no reference no.)

Conductor Pipe Diameter: Not available Depth: Not available

Method of Seal: Not available Depth: Not available

Blank Casing Type: Not available

Perforated Section
Type: Not available
Schedule: 174-193 ft.; 214-239 ft.; 305-360 ft.

Gravel Pack Type: Not available Depth: Not available

Maintenance Records: Not available

Photographic Records: Not available

Water Level and Production Records: Not available

REMARKS: None

MAJOR REPAIRS OR ALTERATIONS:

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

Well No.: 20 Location: Parking lot of building 200

Present Status: Standby source for bldg. 200

Driller: Not available

Method of Construction: Rotary Date of Construction: 1968

Electric Log: Not available Lithology: Not available

Conductor Pipe Diameter: Not available Depth: Not available

Method of Seal: Not available Depth: Not available

Blank Casing Type: 14 inch steel to 600 feet

Perforated Section
Type: 1/8 inch by 3 inch milled slots
Schedule: 178-190 ft.; 234-274 ft.; 338-374 ft.; 494-506 ft.; 564-598 ft.

Gravel Pack Type: Not available Depth: 600 feet

Maintenance Records: Air Force Form 996 - Sheets 1 thru 3 inclusive

Photographic Records: Not available

Water Level and Production Records: Air Force Form 1461

REMARKS:
1) This well was constructed to replace well no 9.

MAJOR REPAIRS OR ALTERATIONS:

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

Well No.: 21-24 Location: Building 696 area; Building 1440 area; Building 1457 area; Building 1465 area

Present Status: Abandoned or destroyed

Driller:

Method of Construction: Date of Construction:

Electric Log: Lithology:

Conductor Pipe Diameter: Depth:

Method of Seal: Depth:

Blank Casing Type:

Perforated Section
Type:
Schedule:

Gravel Pack Type: Depth:

Maintenance Records: Air Force Form 996 - Well at Bldg. 1440
Air Force Form 996 - Well at Bldg. 1457

Photographic Records:

Water Level and Production Records:

REMARKS:

1) These wells have been reported by the Water Department personnel to be "old farm wells" that existed during the early McClellan Air Depot acquisition period.

MAJOR REPAIRS OR ALTERATIONS:

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

Well No.: 25 Location: Lincoln Communication Site - Off base

Present Status: In service

Driller:

Method of Construction: Date of Construction:

Electric Log: Lithology:

Conductor Pipe Diameter: Depth:

Method of Seal: Depth:

Blank Casing Type:

Perforated Section
  Type:
  Schedule:

Gravel Pack Type: Depth:

Maintenance Records:

Photographic Records:

Water Level and Production Records:

REMARKS:
1) This well is several miles east of the study area and therefore is beyond the scope study.

MAJOR REPAIRS OR ALTERATIONS:

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

Well No.: 26 Location: Davis Communication Site - Off base

Present Status: In service

Driller:

Method of Construction: Date of Construction:

Electric Log: Lithology:

Conductor Pipe Diameter: Depth:

Method of Seal: Depth:

Blank Casing Type:

Perforated Section
Type:
Schedule:

Gravel Pack Type: Depth:

Maintenance Records:

Photographic Records:

Water Level and Production Records:

REMARKS:
1) This well is several miles southwest of the study area and therefore is beyond the scope of this study.

MAJOR REPAIRS OR ALTERATIONS:

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

Well No.: 27 Location: Rapcon Facility

Present Status: Abandoned

Driller: Eaton Drilling Corp.

Method of Construction: Rotary Date of Construction: June 1962

Electric Log: Not available Lithology: Calif. Water Well Report

Conductor Pipe Diameter: 12 inches Depth: 71 feet

Method of Seal: Cement grout Depth: 71 feet

Blank Casing Type: 6 inch steel to 261 feet

Perforated Section
Type: 3/16 inch by 1 1/2 inch milled slots
Schedule: 175-185 ft.; 200-210 ft.; 240-260 ft.

Gravel Pack Type: Not available Depth: 261 feet

Maintenance Records: Air Force Form 996 - Sheets 1 and 2

Photographic Records: Not available

Water Level and Production Records: Not available

REMARKS: None

MAJOR REPAIRS OR ALTERATIONS:
1) 8/72 - Pumping equipment removed.

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

==

Well No.: 28 Location: Building 1082

Present Status: In service

Driller: Not available

Method of Construction: Cable tool Date of Construction: 1968

Electric Log: Not available Lithology: Not available

Conductor Pipe Diameter: 12 inch Depth: 72 feet

Method of Seal: Cement grout Depth: 60 feet

Blank Casing Type: 8 inch steel (information from Corp. of Engineers construction drawi
to 236 feet

Perforated Section
Type: Milled slots
Schedule: 144-147 ft.; 205-212 ft.; 233-236 ft.

Gravel Pack Type: None Depth:

Maintenance Records: Air Force Form 996 - 1 sheet

Photographic Records: None available

Water Level and Production Records: None available

==

REMARKS: None

MAJOR REPAIRS OR ALTERATIONS:

McCLELLAN AIR FORCE BASE
Sacramento, California
Contract No. F04699-83-C0666
BASE PRODUCTION WELL DATA

LUHDORFF AND SCALMANINI
Consulting Engineers
Woodland, California

Well No.: 29 Location: Building 1455

Present Status: Out of service due to excessive production of sand.

Driller: The Water Development Corp.

Method of Construction: Reverse Circulation Date of Construction: August 1981

Electric Log: August 1981 - Geo Hydro Data Lithology: Driller field notes

Conductor Pipe Diameter: None installed Depth:

Method of Seal: Cement grout Depth: 53 feet

Blank Casing Type: 16 inch by 3/16 inch wall steel to 604 feet

Perforated Section
Type: 1/16 inch slot louvered (251-401 ft.) and 3/32 inch slot louvered (401-555 ft.)
Schedule: 251-555 feet

Gravel Pack Type: Schwartzgrubers 2:1/3:1 Depth: 53-386 ft/ 386-604 ft

Maintenance Records: Air Force Form 996 - 1 sheet

Photographic Records: None available

Water Level and Production Records: Air Force Form 1461

REMARKS: None

MAJOR REPAIRS OR ALTERATIONS:
1) 1/82 - Well put into operation; Attempt to develope well of sand.
2) 4/82 - Well taken out of service due to excessive production of sand.
3) 4/83 - Pull pump for repair and redevelopment of well.

CHAPTER 5

RECOMMENDATIONS

CHAPTER 5

RECOMMENDATIONS

The following recommendations for the sealing of Base wells have been developed as the result of this investigation. The recommendations are divided into three categories addressing the need for preliminary site investigations, the methodology for sealing Base wells and for added Base maintenance testing of the operation of Base wells and pumps including recommended monitoring well rehabilitation.

1. Preliminary Site Investigation

Chapter 2 discussed the construction of Base production and monitoring wells and cited the limited geophysical data available at McClellan. Chapter 3 described the necessity for obtaining specific data at each production well site prior to sealing, including lithology data supported by geophysical logging, to determine if the gravel pack of each production well is serving as a conduit for the transfer of contaminants by observing the hydraulic gradients of the upper and lower aquifers during production well pumping, and to obtain water quality samples for the determination of water quality of selected aquifers at each site.

Chapter 3 proposed and it is hereby recommended, that a preliminary engineering site investigation, as delineated in that chapter, be performed at Base production wells 1, 2, 12, 18 and 29, wells presently out of service due to the presence of TCE or excessive sand production; wells 8, 10, 11, and 13, wells

currently operational and in service; and wells 4, 11, and 20, operational but on standby.

Such an investigation should include the construction and installation of multiple piezometer wells isolated to monitor the upper and lower aquifers encountered during construction for the purpose of conducting preliminary aquifer analysis prior to the development of final well sealing recommendations. It is the opinion of LSCE that such an investigation could reduce the number of wells required to be sealed and will provide the means to monitor future aquifer behavior both for water quality and hydraulic gradient changes.

2. Base Well Sealing Methodology

Chapter 3 of this report describes various alternatives available for installing seals in the gravel envelopes of existing Base production wells. It is recommended that the secondary remedial cementing operation be performed on selected wells using the Bradenhead squeeze cementing technique. Such procedure requires that the well be cemented from within the existing casing through perforations installed opposite low permeable formations, allowing the annulus between the bore hole and casing wall to be sealed.

Following sealing operations it is recommended that pumping tests be conducted to determine the effectiveness of the seal using the piezometer wells recommended to be installed in the preliminary site investigation.

3. Base Maintenance Practices

Chapter 4 discussed the need for monitoring the specific capacity of Base production wells. It is therfore recommended that calculations of each well's specific capacity be included in the monthly summary of data obtained by Base personnel to allow for the monitoring of well performance, and that such data be incorporated with the existing graphical analysis of each well's water level data.

It is further recommended that rehabilitation of selected monitoring wells constructed during the Phase II Confirmation Study be attempted to determine if the wells are inefficient. If the efficiency of the monitoring wells is improved by rehabilitation, additional pumping tests should be conducted to reevaluate the aquifer characteristics developed during the Phase II Confirmation Study.

APPENDIX A

EXECUTIVE SUMMARY PHASE I - INSTALLATION ASSESSMENT

EXECUTIVE SUMMARY

A. Introduction

1. CH2M HILL was retained by the Air Force Engineering and Services Center (AFESC) on January 26, 1981 to conduct the McClellan AFB Records Search under Contract No. F08637 80 G0010 0002.

2. The identification of hazardous waste disposal sites at military installations was directed by Defense Environmental Quality Policy Memorandum 80-6 dated June, 1980 and implemented by Air Force message dated December 2, 1980 as a positive action to ensure compliance of military installations with the Resource Conservation and Recovery Act (RCRA) and implementing regulations. The Records Search comprises Phase I of the Department of Defense Installation Restoration Program. The main purpose of the Records Search Program is to determine the potential, if any, for migration of toxic and hazardous materials off the installation boundaries.

3. The McClellan AFB Records Search Program included a detailed review of pertinent installation records, contacts with various government and private agencies for documents relevant to the Records Search effort, and an onsite base visit conducted by CH2M HILL during the week of April 27 through May 1, 1981. Activities conducted during the onsite base visit included interviews with past and present key base employees, ground tours of base facilities, and a helicopter overflight to identify past disposal areas. The installations included in the Records Search Program were

McClellan AFB, Camp Kohler Annex, Lincoln Communications Annex, Davis Communications Annex, McClellan Storage Annex, Sacramento River Dock Annex, Middle Marker Annex, and Capehart Family Housing Annex. Figures 1 and 2 give a historical summary of waste disposal practices based on the findings of the Records Search Program.

4. In the event that the Records Search indicates that the potential exists for migration of hazardous contaminants off the installation, Phase II field work would be conducted to confirm the presence of the specific migrating contaminants and to determine the extent of migration. The restoration or containment of the hazardous waste disposal sites would comprise Phase III of the Installation Restoration Program.

B. <u>Conclusions</u>

1. The McClellan AFB Records Search resulted in the identification of two main areas of concern:

   a. Polychlorinated biphenyls (PCBs)

   b. Trichloroethylene (TCE) ground-water contamination

2. The Arcade Water District reported water quality degradation (high total dissolved solids) in a production well located near Camp Kohler.

   No indication was found from the records or from the interviews of hazardous waste disposal or contaminant migration at the other installations included in the Records Search, i.e., Lincoln

Communications Annex, Davis Communications Annex, McClellan Storage Annex, Sacramento River Dock Annex, Middle Marker Annex, and Capehart Family Housing Annex.

C. Recommendations

1. Sampling, monitoring, and clean-up measures need to be implemented at the PCB-contaminated site located at the northwest corner of the runway clear zone. The possible existence of past burial pit(s) at the site (unconfirmed report from one of the interviewees) needs to be verified, e.g., by seismic survey of the area. If the existence of one or more burial pits is confirmed, then exploratory soil sampling and ground-water monitoring should be done to determine the extent, if any, of subsurface PCB contamination at the site.

2. McClellan should immediately implement an expanded monitoring program to determine the source(s) and the extent of TCE ground-water contamination. The expanded monitoring program should include:

   a. Initial geophysical logging and selected sampling of Base Wells 1, 2, 12, 18, and 28.

   b. The design of an expanded monitoring well program based on an analysis of data obtained from the initial geophysical logging and sampling effort.

   c. Routine monitoring of nearby offbase City and private wells. The offbase monitoring should be a joint cooperative effort involving

McClellan AFB, the City, the California Regional Water Quality Control Board, and the Department of Health Services.

3. The final details of the expanded monitoring program should be developed with input from the California Regional Water Quality Control Board and the U.S. Geological Survey.

4. The restoration and/or containment of the contaminant source(s) should commence as soon as sufficient information is obtained from the expanded follow-on studies to pinpoint the location(s) and extent of contaminant migration..

5. Further investigations should be conducted in cooperation with the Arcade Water District to determine the source of water quality degradation in Arcade Well No. 31. The investigations should include a detailed review of available water quality data, well logs, and well construction details for the two Camp Kohler supply wells and Arcade Wells No. 31, 16, 44, and 56.

The details are expanded and discussed in the body of the report which follows and which contains supporting data.

APPENDIX B

CONCLUSIONS AND RECOMMENDATIONS PHASE II - CONFIRMATION

EXECUTIVE SUMMARY

INTRODUCTION

The United States Air Force, due to its primary mission to militarily defend the United States through the operation and maintenance of aircraft, has long been engaged in a wide variety of operations that require handling toxic and hazardous materials. Federal, state, and local governments have developed strict regulations that require disposers of these materials to identify the locations and contents of waste disposal sites and to implement action to eliminate any hazards to the public health or the environment. The Department of Defense (DOD) has issued Defense Environmental Quality Program Policy Memorandum 81-5 which requires the identification and evaluation of past hazardous material disposal sites on DOD property, the control of migration of hazardous contaminants, and the control of hazards to the public health and welfare that resulted from these past operations. This program is called the Installation Restoration Program (IRP). The IRP serves as a basis for response actions on Air Force installations under the provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980.

The Installation Restoration Program has been developed as a four-phased program. These phases are:

- Phase I - Installation Assessment
- Phase II - Confirmation
- Phase III - Technology Base Development
- Phase IV - Operations

Phase I, completed at McClellan Air Force Base in July 1981, includes the identification and prioritization of past disposal sites that could pose a hazard to public health or the environment as a result of contaminant migration. Phase II consists of a comprehensive preliminary

environmental survey to define and quantify the presence or absence of contamination that may adversely affect public health or the environment. During Phase III, a data base will be developed upon which to prepare a comprehensive contaminant control plan. This contaminant control plan will be implemented in Phase IV.

This report describes the work performed during the Phase II program at McClellan AFB, California, including development of recommendations for follow-on actions and future monitoring.

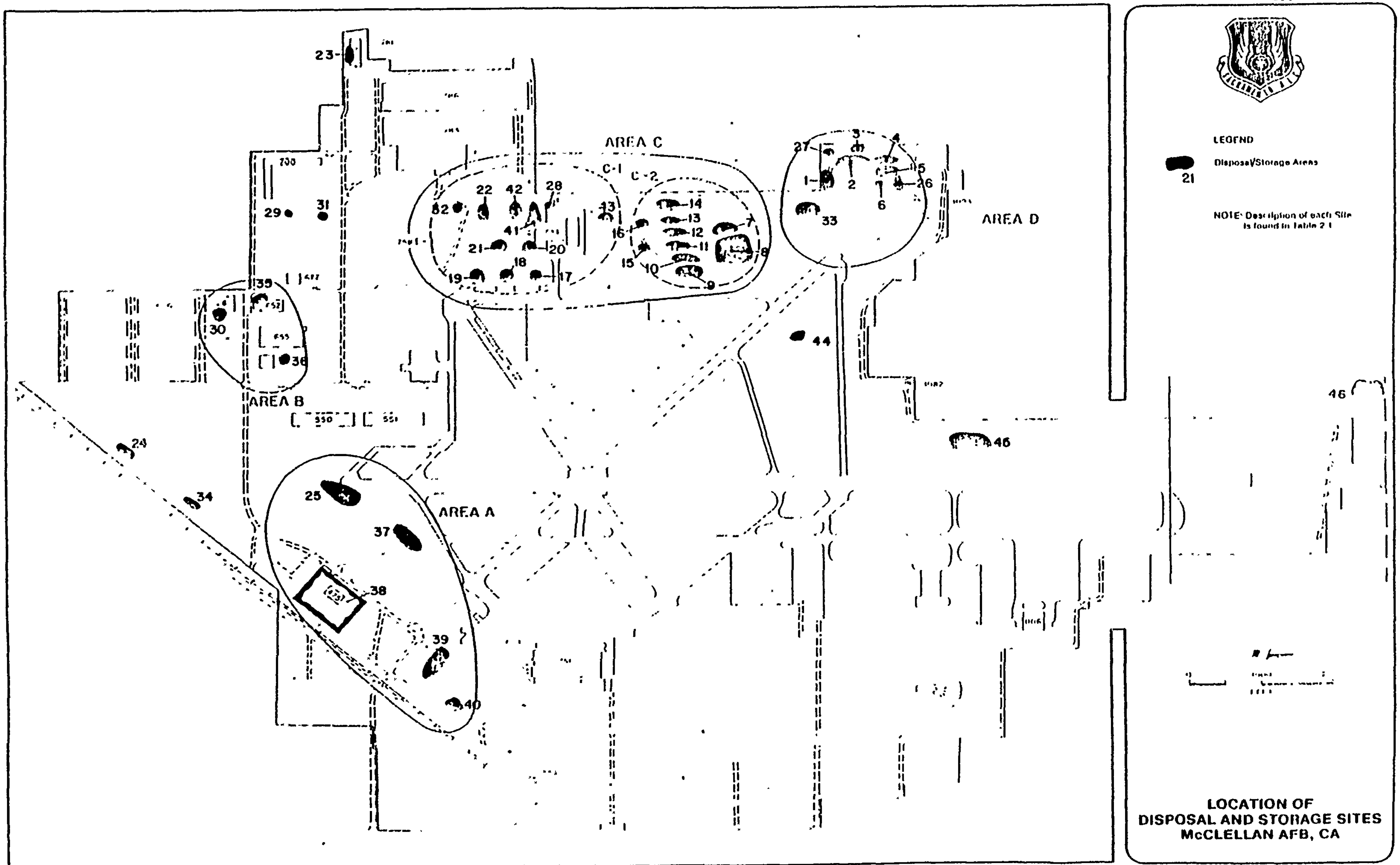
The Phase I study was a records search assessing the potential for groundwater quality problems on McClellan AFB (CH2M Hill, 1981). The Phase I report included information generated by the Air Force in a study entitled "Investigating Ground Water Contamination as of 30 April 1981" (Brunner and Zipfel, 1981). The records search program resulted in the identification of two main areas of concern. These were (1) organic solvents found to be present in groundwater and (2) polychlorinated biphenyls (PCB's) contained in soil in a small area located at the northwest corner of the runway clear zone as a result of previous land owner activities. The soils containing PCB's were removed by the Air Force and transported to an approved PCB site. The Phase I report recommended the implementation of an expanded monitoring program in Phase II to determine the extent of organic constituents in groundwater. The results of that program are discussed in this report.

Forty-six active and inactive waste disposal and storage sites were identified in the Phase I report. Using the Air Force's Hazard Assessment Rating Methodology (HARM System), the sites were evaluated on the basis of site characteristics, potential for contamination, waste characteristics, and waste management practices. Most of the sites were envisioned as forming four discrete site clusters across the Base. The estimated locations of these sites and site clusters are illustrated on Figure E.1. In some instances the exact site location is unknown.

FIELD PROGRAM

Prior to the development of the field program an extensive review of existing information on geologic conditions and aquifer systems was conducted. Based on that information and specific recommendations from

FIGURE E.1



LOCATION OF
DISPOSAL AND STORAGE SITES
McCLELLAN AFB, CA

ENGINEERING-SCIENCE

the Phase I report, a field program was developed that included installing monitoring wells, analyzing groundwater samples, conducting aquifer tests, investigating an industrial waste line, and locating an abandoned Base water supply well.

The drilling program at McClellan AFB was implemented in two successive stages. A total of 48 monitoring wells were installed during this two-phased program. The location and depth of Stage I monitoring wells were determined on the basis of existing hydrogeological information for the Base (primarily well logs from previously installed monitoring and water supply wells) and location of past disposal and storage areas on the Base. The Stage II drilling program was designed on the basis of analytical results obtained for the Stage I groundwater samples. Pump and slug tests were conducted to evaluate the transmissibility of water-bearing sands and lateral and vertical continuity between each sands zone. One pump test and three slug tests were performed. Seven wells were tested for specific conductance and temperature in the field. Readings were taken in wells to determine whether stratification was evident within a well and whether detectable differences could be noted between the shallow and deeper aquifers.

Part of the Stage I field program included establishing the location of Base production well 7. This was necessary since it was thought that well 7 could be a conduit for water to travel from near the surface down to lower production aquifers. Abandonment of the well in past years left no clue on the surface as to its location. A search of Base utility records showed the approximate location to be near the west side of Building 475 in an underground well house. The buried well building was located with a magnetic flux indicator (Schonstedt GA-52 Magnetic Locator), and the site was excavated for evaluation of the well head. The well head, located in the building basement, was found to be encased with concrete and fitted with a non-watertight fabricated steel cap; the gravel pack was sealed by a 24-inch outer casing. A watertight cap was installed on the 24-inch casing, in addition to a supplemental lockable steel cap. The well was found to be obstructed at an 80-foot depth, even after attempted clean-out of the well by rotary-wash drilling. Evidence from Base personnel interviews indicates the well casing

probably was grouted in the late 1960's or early 1970's. Because a substantial amount of excess water from fill material drained into the well during excavation, sampling of BW7 for priority pollutants was not accomplished.

An investigation of the industrial waste collection system in the vicinity of Building 251 was performed in January 1982. The purpose of this investigation was to determine if the industrial waste line was a possible source of constituents that necessitated closure of two Base production wells in the immediate vicinity. The investigation included three soil borings beneath the line.

FINDINGS

Results of the field program demonstrated that the Base is underlain by a shallow sands zone at depths ranging from approximately 80 to 100 feet below ground surface. This zone varies in thickness from 1 foot to 17 feet and may be discontinuous in places. Permeabilities range from 0.8 to 4.2 gpd per square foot, and transmissibilities range from 4.7 to 21 gpd per foot. The groundwater in this zone moves in a south-southwesterly direction and is influenced locally primarily by off-base production wells. Based on physical characteristics, it appears that groundwater in this zone would move off Base no more than 1,000 feet in 40 years. However, localized pumping may accelerate this rate. Deeper aquifers exist, disconnected from the shallow sands and separated by at least 20 feet of predominately fine-grained material.

Since off-base wells may have been constructed with gravel packs and perforations in the shallow sands zone, constituents in groundwater (that could be the result of past McClellan AFB waste disposal practices) could migrate downward into lower aquifers causing water quality problems with off-base water supply wells. Sufficient time has passed since the disposal of waste material on McClellan property for constituents in the first sands beneath the Base to cause problems in public and private water supply wells.

Groundwater samples from all wells on the Base were analyzed for selected organic and inorganic constituents. The shallow aquifer (first sands zone) shows the presence of constituents particularly along the

western border of the Base where former disposal sites existed. However, the data also show organic compounds and trace metals in shallow wells throughout the Base; often, these wells were not located near a known disposal area. The occurrence of these constituents in wells with no apparent known source indicates that the delineation of plumes from individual site locations may not be possible.

Numerous factors contribute to the fact that identification of constituent plumes in groundwater from individual sites on Base may be impossible. These factors include potentially unknown sites and varying groundwater table elevations, as well as the operation of disposal sites at different times. In addition, in many cases groundwater has flowed beneath several sites, picking up constituents from one or more areas. It is possible that chemical constituents may be identified in downgradient areas off the Base. The interface between areas containing detectable constituents and those areas which do not could be considered the leading edge of a plume. Phase II of the IRP did not provide for any off-base activity, so plume movement outside the boundaries of the Base was only estimated.

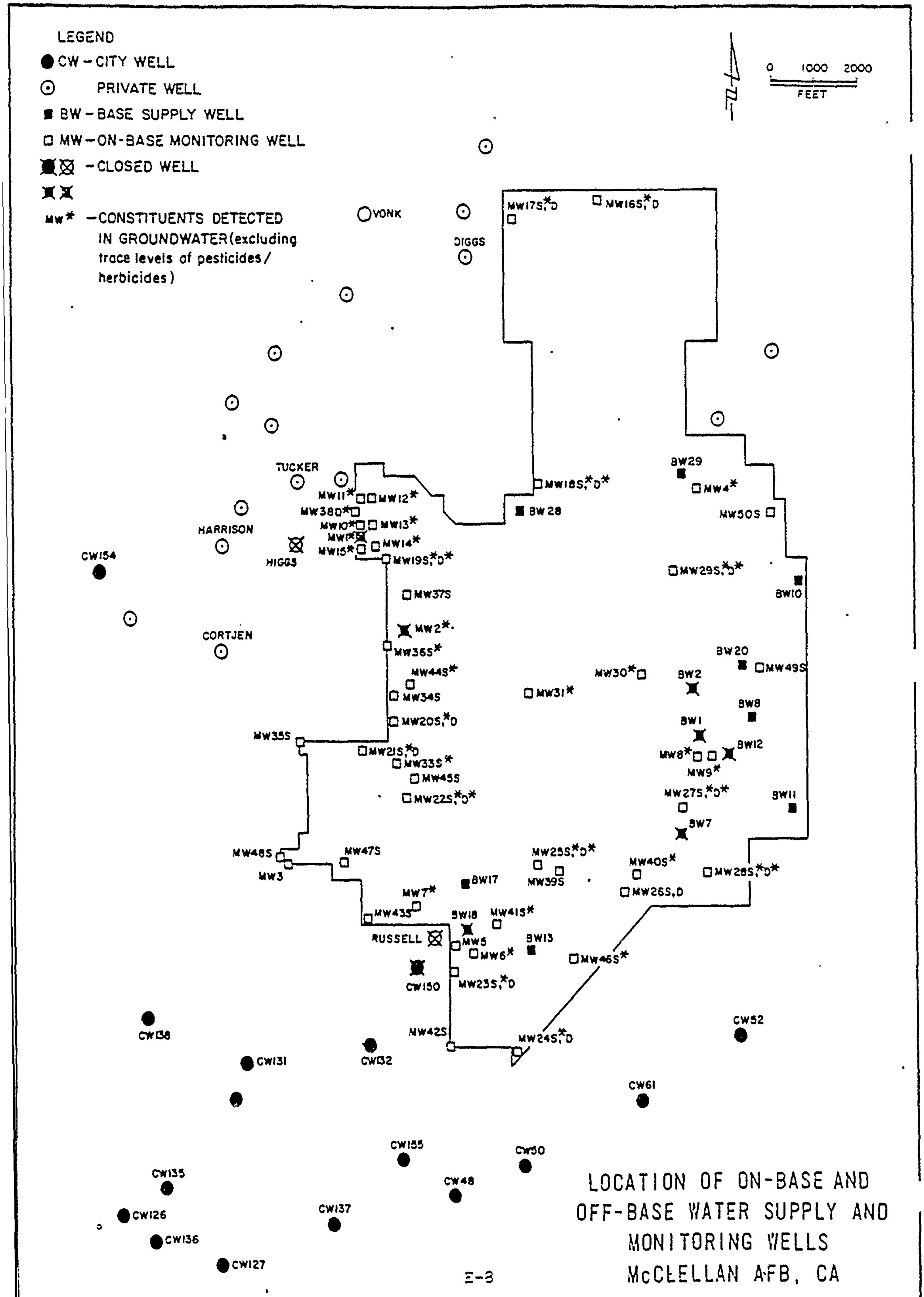
The deeper aquifer (second sands zone) shows constituents near or below limits of detection, except pesticides and herbicides. A deep well located downgradient of the sludge pit area in the northwest corner of the Base clearly shows an absence of constituents, even though it is situated in an area exhibiting "worst case" conditions.

Selected analyses of wells showed negative results in most cases. PCB analyses of all monitoring wells installed on the Base during Stages I and II resulted in non-detectable concentrations. However, aroclor (a polychlorinated biphenyl) was present above detection limits in one Base production well in a single sampling event. Low concentrations of cyanide were detected in six monitoring wells on the Base, including one well installed at the upgradient Base boundary. A seventh well contained an elevated cyanide concentration. Cresylic acid was detected in a shallow well placed between the suspected source (Building 475) and Base production well 7 (abandoned). Two wells (shallow and deep) placed downgradient from production well 7 did not contain cresylic acid. Aliphatic material (grease and oil) appeared at elevated concentrations in

one well along the western edge of the Base. This material has not reached the second aquifer but has migrated in a southerly direction.

The presence of herbicides and pesticides in all of the shallow wells and most of the deeper wells is universal across the Base. Concentrations vary from one well location to another, and from one sampling to the next within the same well. The actual appearance of a particular compound is not consistent. One sampling often shows a compound that is not detected during a subsequent sampling. The source of these herbicides and pesticides in the groundwater may be partially from Base application and/or disposal. However, monitoring wells placed upgradient at the extreme north end of the Base show the presence of herbicides and pesticides in the shallow and deep aquifers. The source of groundwater for both wells is off Base from the north. Herbicides and pesticides are therefore being contributed to on-base groundwater from off-base sources. Historical records do show that two off-base production wells north of the Base contain 2,4,5-TP (Silvex). The occurrence of these herbicides and pesticides appears to be ubiquitous.

Figure E.2 depicts the location of all monitoring wells on the Base, and denotes those wells where measurable concentrations of most constituents were identified. A general range of constituent concentrations found in all on-base shallow wells is compiled in Table E.1. These data reflect results only for constituents identified at measurable levels in at least one well. Analytical reports which present comprehensive results for all constituent analyses performed are contained in the appendices. Constituent values lower than the detection limits were not used to calculate the range of concentration except for those constituents found at detectable levels in only one or two shallow groundwater samples. For these constituents, it was not possible to tabulate low and/or median concentrations representing measurable quantities. In these instances, trace level data and "not detected" results were used to establish the range of concentration. The source areas in which the high concentrations were found are noted in the table. Table E.2 provides a range of the most common volatile organic constituent concentrations from different source areas.



LOCATION OF ON-BASE AND OFF-BASE WATER SUPPLY AND MONITORING WELLS McCLELLAN AFB, CA

TABLE E.1

RANGE OF CONSTITUENT CONCENTRATIONS
DETECTED IN BASE MONITORING WELLS AND
STAGE I AND II SHALLOW WELLS

Constituent[a]	Unit of Measurement	Minimum Detection Level	Source Area[b]	Concentration High	Concentration Low	Concentration Median
Volatiles						
benzene	ppb	10.0	D	680	10	45
carbon tetrachloride	ppb	1.0	A	25	ND[c]	<10
chloroform	ppb	1.0	D	120	5	20
1,1-dichloroethane	ppb	1.0	D	250	19	110
1,2-dichloroethane	ppb	1.0	D	17	ND	ND
1,1-dichloroethylene	ppb	1.0	D	63,000	5	2,500
1,2-trans-dichloroethylene	ppb	1.0	D	200	6	80
ethylbenzene	ppb	1.0	C-1	220	ND	<10
methylene chloride	ppb	1.0	D	5,000	1,000	3,000
tetrachloroethylene	ppb	1.0	D	70	5	18
toluene	ppb	1.0	C-1	440	5	50
1,1,1-trichloroethane	ppb	1.0	D	12,000	55	2,300
trichloroethylene	ppb	1.0	D	14,100	0.54	61
trichlorofluoromethane	ppb	1.0	D	7	ND	ND
vinyl chloride	ppb	1.0	D	50	20	25
Acid Compounds						
2,4-dimethylphenol	ppb	1.0	D	94	ND	19
pentachlorophenol	ppb	1.0	DBB	260	6	15
phenol	ppb	10.0	D	400	<10	<10
Base/Neutral Compounds						
anthracene	ppb	1.0	C-1	220	ND	<10
bis(2-ethylhexyl)phthalate	ppb	1.0	C	230	8	20
1,2-dichlorobenzene	ppb	1.0	D	100	21	32
1,3-dichlorobenzene	ppb	1.0	D	28	<10	8
1,4-dichlorobenzene	ppb	1.0	D	40	10	12
di-n-butyl phthalate	ppb	1.0	C-1	9	ND	<10
fluorene	ppb	1.0	C-1	90	ND	ND
naphthalene	ppb	1.0	C-1	90	<10	25
1,2,4-trichlorobenzene	ppb	1.0	D	12	4	8
Pesticides/Herbicides						
Aldrin	ppb	0.003	D	6.97	0.041	0.503
alpha-BHC	ppb	0.002	A	0.08	0.018	0.032
beta-BHC	ppb	0.004	DBB	0.142	0.007	0.048
delta-BHC	ppb	0.004	C-1	0.83	0.025	0.066
gamma-BHC (lindane)	ppb	0.002	DBB	2.76	0.005	0.038
2,4-D	ppb	0.001	C-2	0.56	0.003	0.063
2,4,5-T	ppb	0.001	C-1	0.087	0.002	0.005
2,4,5-TP (Silvex)	ppb	0.002	D	0.36	0.004	0.051
dieldrin	ppb	0.006	D	0.20	<0.006	<0.006

TABLE E.1 (Continued)

Constituent[a]	Unit of Measurement	Minimum Detection Level	Source Area[b]	Concentration High	Concentration Low	Concentration Median
endosulfan sulfate	ppb	0.03	C	0.011	<0.03	<0.03
heptachlor	ppb	0.002	DBB	0.80	0.013	0.056
heptachlor epoxide	ppb	0.004	DBB	0.17	0.007	0.027
Metals						
antimony	mg/l	0.005	D	0.06	0.006	0.008
arsenic	mg/l	0.05	D	0.66	0.24	0.30
cadmium	mg/l	0.01	UIA	0.08	0.01	0.014
chromium	mg/l	0.05	D	4.17	0.07	0.12
copper	mg/l	0.05	D	1.18	0.12	0.33
lead	mg/l	0.01	A	0.98	0.01	0.023
mercury	mg/l	0.0005	UBB	0.0027	0.0005	0.0012
nickel	mg/l	0.05	UIA	2.13	0.05	0.08
selenium	mg/l	0.01	D	0.355	0.01	0.049
zinc	mg/l	0.02	DBB	11.4	0.02	0.07
Selected Analyses						
cresylic acid (Cresol)	$\mu g/l$	5	A	26	<5	Ø[d]
cyanide	mg/l	0.02	UIA	0.95	0.02	0.03

a List of constituents excludes those which were not detected in any shallow groundwater sample. A total of 77 constituents were tested and not found above detection limits. Comprehensive results for all analyses performed are contained in Appendices K, L, and M.

b Area in which high concentration was detected:
- A - Area A
- C - Area C
- C-1 - Subarea C-1
- C-2 - Subarea C-2
- D - Area D
- DBB - Downgradient Base Boundary
- UBB - Upgradient Base Boundary
- UIA - Upgradient Base Industrial Area

c ND - Not detected

d Ø - Analyses were performed for only two shallow groundwater samples.

TABLE E.2

RANGE OF VOLATILE ORGANIC CONSTITUENT CONCENTRATIONS IN SHALLOW GROUNDWATER FROM DIFFERENT SOURCE AREAS

Source Area	Disposal Sites Upgradient From Affected Wells Containing Volatile Organics	Range of Concentrations of Most Common Volatile Constituents in Groundwater
AREA A	25,37,38,34,40	trichloroethylene: ND-50 ppb
AREA B	30,36	1,1-dichloroethylene: ND-5 ppb 1,2-trans-dichloroethylene: ND-10 ppb trichloroethylene: ND-118 ppb
SUBAREA C-1	41,42,43	ethylbenzene: ND-220 ppb toluene: ND-440 ppb trichloroethylene: ND-2,000 ppb
SUBAREA C-2	7,8,9,10,11,12, 13,14,15,16	1,1-dichloroethylene: ND-30 ppb tetrachloroethylene: ND-5 ppb trichloroethylene: ND-10 ppb
AREA D	1,2,3,4,5,6,26,27	1,1-dichloroethylene: 500-63,000 ppb 1,1,1-trichloroethane: ND-12,000 ppb trichloroethylene: 160-14,100 ppb

ND - not detected

Analytical results of groundwater samples from the deeper water-bearing materials indicate the deeper zone is "cleaner" than the shallow aquifer, with constituents mostly near or below limits of detection except for pesticides and herbicides. In general, the deeper sands appear to contain no EPA priority pollutants; the absence of constituents is consistent at most well locations.

All three soil borings beneath the industrial waste line contained trace metals, specifically arsenic and selenium, at both the 15-foot and 20-foot depths.

CONCLUSIONS

Past waste disposal practices at McClellan AFB have resulted in the creation of three types of problems. These are (1) affected materials (disposed waste and soils), (2) on-base water supply, and (3) off-base water supply. The groundwater affected by past disposal activities appears to be limited primarily to the shallow sands zone. That zone, which varies in thickness from 1 foot to 17 feet, is a very poor producer of water. Based on estimated groundwater velocities, constituents in the shallow sands have probably migrated outside Base boundaries up to a distance of 1,000 feet. However, this rate of movement may be accelerated by local pumping. Private and public water supply wells located off the Base are most likely gravel packed to depths exceeding 50 feet below the ground surface, with perforations possibly at greater depths. The deeper water-bearing sands are probably continuous off Base where they are tapped by private and public wells for water supply.

RECOMMENDATIONS

Recommended follow-on actions and future monitoring for each problem area are summarized in Table E.3.

TABLE E.3

RECOMMENDED ACTIONS AND MONITORING
McCLELLAN AFB, CALIFORNIA

Problem	Recommended Action and Monitoring	Rationale	Implementation Priority[a]
Affected Materials	• Ensure that Sites 8 and 40 are closed to meet RCRA requirements	• Prevent precipitation moisture from contacting affected materials/Meet RCRA requirements	2
	• Close Site 4 to meet RCRA requirements to include placing 4 feet of soil/cement mixture within the pit, and subsequently cap the site to prevent surface infiltration	• Absorb moisture on pit surface/ Prevent precipitation moisture from contacting affected materials	1
	• Inspect sites in Area A (25), Area B (30), Subarea C-1 (41, 42, 43), Subarea Subarea C-2 (7, 8, 9, 10, 11), and Area D (2, 3, 4, 5, 6, 26, 27) to evaluate status of surface conditions. Cover sites with impermeable cap designed to divert surface water from the site	• Prevent precipitation moisture from contacting affected materials	• Area D: 2 • Subarea C-1: 3 • Area B: 3 • Subarea C-2: 4 • Area A: 4
On-Base Water Supply	• Seal gravel pack on Base production wells 1, 8, 13, 18, 20, and 29 • Abandon BW2 and seal gravel pack • Seal gravel packs in MW1, 2, 3, and 4	• Prevent affected shallow groundwater from entering Base water supply system	2
	• Rehabilitate industrial waste line in front of Building 251	• Minimize amount of exfiltration from pipeline to the first sands zone	2
	• Remove manhole 33A and associated lines	• Prevent accumulation of sludge and eliminate potential contamination	2
	• Conduct investigation on remaining Base industrial waste line	• Identify potential areas of exfiltration into the first sands zone	3
	• Sample monitoring wells annually and Base production wells monthly[b]	• Monitor wells to determine effectiveness of corrective measure	1
Off-Base Water Supply	• Inform local governmental agencies of the need to set up regulations that require a 120-foot sanitary seal for new wells installed in the area	• Prevent new wells from providing migration route between water-bearing zones	1

TABLE E.3 (Continued)

Problem	Recommended Action and Monitoring	Rationale	Implementation Priority[a]
	• Inform local agencies of the need to seal gravel packs to a depth of 120 feet on private and public wells along affected Base boundaries	• Prevent shallow groundwater entering water supply wells	1
	• Inform local agencies of the need to monitor public and private wells semiannually within a 5,000-foot radius of affected Base boundaries[b]	• Provide early detection of downgradient migration of affected shallow groundwater	1
	• Investigate feasibility of constructing interception system along affected Base boundaries	• Develop system to prevent off-base migration of affected groundwater	3

a Priorities are ranked with 1 being highest and 4 the lowest.
b Well samples should be analyzed for: volatile compound (TCE); acid compound (pentachlorophenol); base/neutral compound (1,2-dichlorobenzene).

CHAPTER 6

RECOMMENDATIONS

The following recommendations for preventive or corrective measures will accomplish the protection of public health on and off the Base, as well as mitigation of environmental impacts that have occurred or may occur off Base as a result of past disposal and storage practices at McClellan AFB. The recommendations are divided into three categories addressing the impacts of affected materials, on-base water supply, and off-base water supply. These recommendations are summarized on Table 6.1. Included with the recommendations is a recommended priority for implementation.

AFFECTED MATERIALS

Chapter 5 discussed the estimated volume of affected disposed material as well as the total volume of affected material reaching to the shallow groundwater. The extensive volumes which would require disposal or treatment following excavation would cause this approach to be prohibitively costly. Table 4.23 delineated the sites that may have affected groundwater quality. Excavating solely the disposed material in these sites would amount to over an estimated one million tons of material to be hauled and disposed. Removal of the affected materials would not mitigate the existing shallow groundwater quality problems.

It is therefore recommended that Sites 4, 8, and 40 be closed to meet RCRA requirements. This will entail development of a closure and post-closure plan that must be approved by the California Department of Health Services. Disposal site 4, the currently open sludge pit, should be abandoned by placing 4 feet of soil/cement mixture into the pit to absorb available moisture. The site should then be graded and capped with impermeable material to prevent infiltration of surface moisture.

TABLE 6.1

RECOMMENDED ACTIONS AND MONITORING
McCLELLAN AFB, CALIFORNIA

Problem	Recommended Action and Monitoring	Rationale	Implementation Priority[a]
Affected Materials	• Ensure that Sites 8 and 40 are closed to meet RCRA requirements	• Prevent precipitation moisture from contacting affected materials/Meet RCRA requirements	2
	• Close Site 4 to meet RCRA requirements to include placing 4 feet of soil/cement mixture within the pit, and subsequently cap the site to prevent surface infiltration	• Absorb moisture on pit surface/ Prevent precipitation moisture from contacting affected materials	1
	• Inspect sites in Area A (25), Area B (30), Subarea C-1 (41, 42, 43) Subarea C-2 (7, 8, 9, 10, 11), and Area D (2, 3, 4, 5, 6, 26, 27) to evaluate status of surface conditions. Cover sites with impermeable cap designed to divert surface water from the site	• Prevent precipitation moisture from contacting affected materials	• Area D: 2 • Subarea C-1: 3 • Area B: 3 • Subarea C-2: 4 • Area A: 4
On-Base Water Supply	• Seal gravel pack on Base production wells 1, 8, 13, 18, 20, and 29 • Abandon BW2 and seal gravel pack • Seal gravel packs in MW1, 2, 3, and 4	• Prevent affected shallow groundwater from entering Base water supply system	2
	• Rehabilitate industrial waste line in front of Building 251	• Minimize amount of exfiltration from pipeline to the first sands zone	2
	• Remove manhole 33A and associated lines	• Prevent accumulation of sludge and eliminate potential contamination	2
	• Conduct investigation on remaining Base industrial waste line	• Identify potential areas of exfiltration into the first sands zone	3
	• Sample monitoring wells annually and Base production wells monthly[b]	• Monitor wells to determine effectiveness of corrective measure	1
Off Base Water Supply	• Inform local governmental agencies of the need to set up regulations that require a 120-foot sanitary seal for new wells installed in the area	• Prevent new wells from providing migration route between water-bearing zones	1

TABLE 6.1 (Continued)

Problem	Recommended Action and Monitoring	Rationale	Implementation Priority[a]
	• Inform local agencies of the need to seal gravel packs to a depth of 120 feet on private and public wells along affected Base boundaries	• Prevent shallow groundwater entering water supply wells	1
	• Inform local agencies of the need to monitor public and private wells semiannually within a 5,000-foot radius of affected Base boundaries[b]	• Provide early detection of downgradient migration of affected shallow groundwater	1
	• Investigate feasibility of constructing interception system along affected Base boundaries	• Develop system to prevent off-base migration of affected groundwater	3

a Priorities are ranked as 1 being highest and 4 the lowest.
b Well samples should be analyzed for: volatile compound (TCE); acid compound (pentachlorophenol); base/neutral compound (1,2-dichlorobenzene).

No further action is recommended for Site 46, from which soils containing PCB's have been removed by the Air Force and transported to an approved PCB site.

To prevent precipitation moisture from contacting affected materials it is recommended that sites found to impact groundwater quality be capped with an impermeable barrier. The barrier may be constructed of asphalt, concrete, clay, or other suitable material depending on the individual site location in relation to Base activities. Each site should be inspected to determine if a cap is necessary. This inspection may include physical and chemical analysis of surface materials. Affected sites and corresponding areas are delineated on Table 6.1. Because of the level of constituents in the groundwater beneath Area D it is recommended that sites in this area be given top priority.

ON-BASE WATER SUPPLY

To protect the on-base water supply it is recommended that Base production wells known to have gravel-packed casings be sealed by slant drilling at depths from 75 feet to 120 feet. This would include Base wells 1, 7, 8, 18, 20, and 29. For Base wells 10, 11, 12, and 13, for which no well logs exist, video cameras should be lowered into the wells to ascertain whether they were constructed by cable-tool methods. If they were constructed by cable tool, there would be no gravel packs, and the wells would require no further corrective measures. If the wells did have gravel packs, sealing would be required by slant drilling. Base well 2, with perforations starting at 100 feet, is located in an inaccessible well house. The well house should be removed and the well abandoned by pressure grouting the gravel pack through existing perforations.

Base monitoring wells 1, 2, 3, and 4 should be abandoned by sealing the gravel pack. This can be accomplished by pressure grouting directly into the well casings; the grout would flow through the perforations and move into the gravel packs.

Although the industrial waste line near Building 251 was found to have potential exfiltration problems, the constituents in water from nearby closed production wells were not the same as those found in the

soil beneath the line. However, the industrial waste line could be a constant source of water for recharge into the first sands zone. In addition, trace metals were found n soils beneath the industrial waste line which could leach into the water-bearing zone. To eliminate this possibility other portions of the industrial waste line should be examined across the Base. The line in front of Building 251 should be surveyed and inspected for structural integrity, then repaired or replaced depending on the results of the survey. Abandoned manhole 33A and the inlet and outlet lines should be removed.

After sealing Base supply wells and Base monitoring wells, monitoring should be implemented on a regular basis and should continue indefinitely until such time as deemed no longer necessary. As noted on Table 6.2, Base supply wells should be monitored monthly and all monitoring wells should be monitored annually. Constituents to be analyzed should include a tracer from the following groups: volatile compounds (TCE), acid compounds (pentachlorophenol), and base/neutral compounds (1,2-dichlorobenzene).

TABLE 6.2

MONITORING PROGRAM FOR ON-BASE AND OFF-BASE WELLS
McCLELLAN AFB, CALIFORNIA

Wells to be Monitored	Monitoring Frequency[a]
Base Production Wells	Monthly
Monitoring Wells	
Base monitoring wells	Annually
Stages I and II wells	Annually
Off-Base Wells	
City Wells (150,132,131,137,127,136,126,138, 135,155,50,48,61, and 52)	Semiannually
Private Wells 13 wells west of Base within 5,000-foot radius	Semiannually

a All wells should be analyzed for:
1. Volatile compound (TCE)
2. Acid compound (pentachlorophenol)
3. Base/neutral compound (1,2-dichlorobenzene)

OFF-BASE WATER SUPPLY

It is recommended that efforts to protect off-base water supply be initiated immediately by informing local agencies of the need to seal affected well gravel packs to a depth of 120 feet. In addition, contacts should be initiated with the local regulatory agencies to ensure that new wells being installed downgradient from the Base boundaries are grouted to a minimum depth of 120 feet.

Because of the geological formation of the first water-bearing sands beneath McClellan AFB, pumping removal of affected water or injection of grout curtains or slurry walls is not practical. The installation of a French drain by conventional trenching and shoring techniques is also not feasible because of the depth to groundwater. To prevent future migration of affected shallow groundwater off Base it is suggested that investigations be initiated to determine the feasibility of construction of an interception drain system along affected Base boundaries.

If such a system is determined to be feasible, individual drain units could be installed at about 1,000-foot intervals along affected Base boundaries. Evacuated water then could be pumped to the existing industrial wastewater system or to a small package treatment unit. Based on flow calculations the treatment system would have to be large enough to handle between 15 and 20 gallons/minute from the entire downgradient Base boundary. Treatment would probably consist of air stripping, carbon adsorption, and possibly coagulation/flocculation. The exact nature of the treatment system would be determined by performing pilot tests on groundwater samples.

It is recommended that the development of an interception pipe be initiated as a Phase III action under IRP. Since this is an unproven technology it is recommended that a scaled-down field demonstration be conducted to evaluate feasibility. If feasibility is proven then installation of such a system downgradient from Area D is recommended. That installation would include intensive monitoring to determine full-scale system effectiveness. If proved effective the system would then be installed downgradient from other areas in the following priority: Subarea C-1, Area B, Subarea C-2, and Area A.

APPENDIX C

BRUNNER - ZIPFEL APPENDIX 4

APPENDIX 4
LOCAL GEOLOGY AND GROUND WATER STUDY
McClellan and Surrounding Area

Understanding the groundwater of a geographical area requires a study of the vertical and horizontal distribution of water in the subsurface geologic formations. Beneath the Sacramento Valley, in which McClellan AFB is located, lies a vast groundwater basin. The Sacramento Valley is the northern half of the Central Valley which constitutes California's largest groundwater basin. The Sacramento Valley is bounded on the east by the Sierra Nevada and Cascade Mountain Ranges and on the west by the North Coast Range. Beneath the relatively flat valley floor is a thick sequence of sedimentary materials deposited in both marine and nonmarine environments.[1]

McClellan is underlain by a sequence of layers, or strata of sand, silt, and clay several hundreds and probably thousands of feet in thickness. These deposits have been slowly accumulated over the last 100 million years. Underneath this accumulation is a floor of bedrock of a type similar to that now exposed in the Sierra Nevada. Three formations (associated with geologic eras) are found in the first thousand feet below McClellan-the Victor, Fair Oaks, and Mehrten formations. Figure 4-1 illustrates this geologic structure.[1,2]

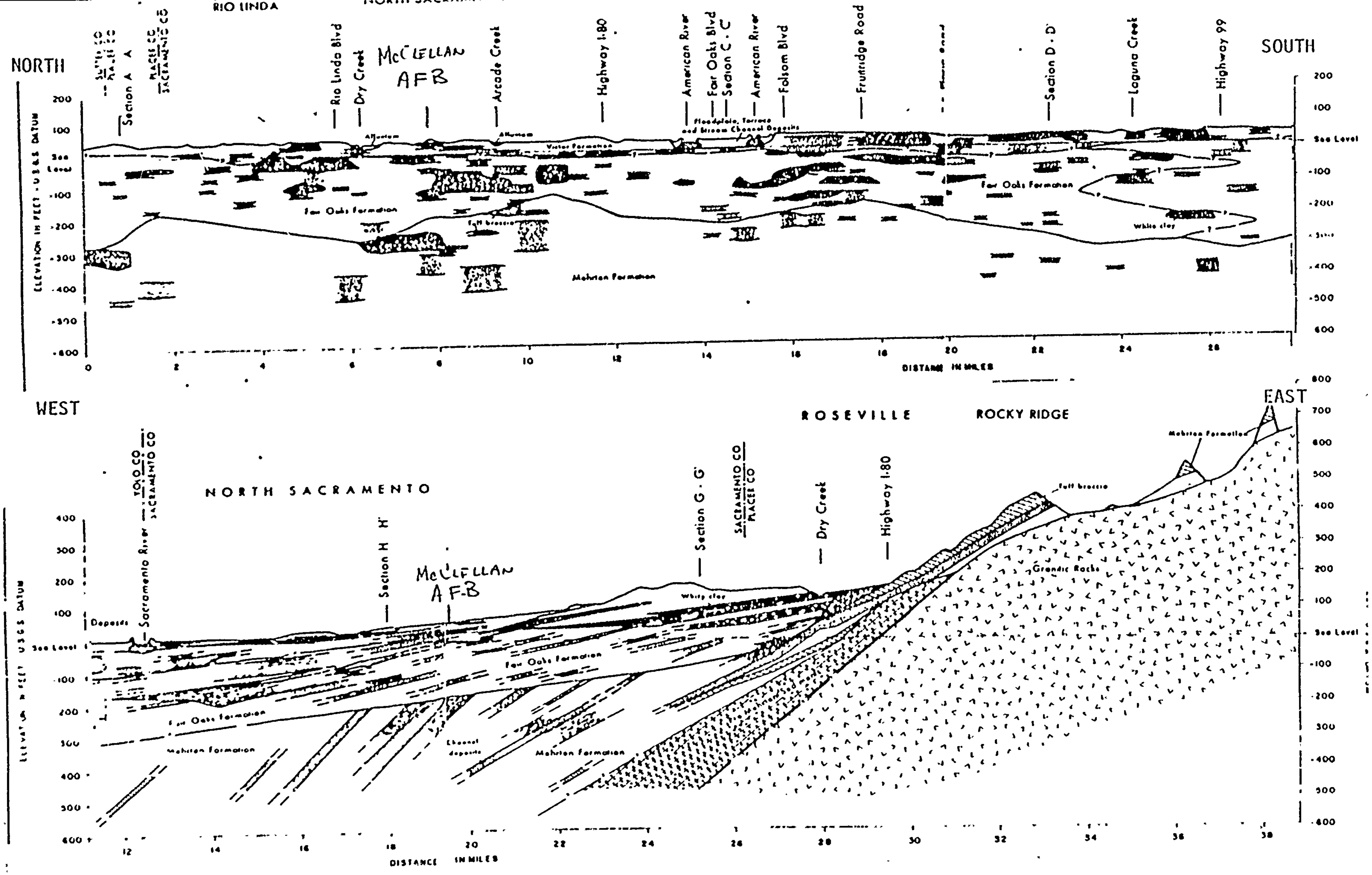
As the youngest of the three formations, the Victor Formation ranges from the surface to approximately 75 feet beneath McClellan. The surface soil is generally a layer of hardpan. The subsurface consists of normally dense interbedded sand, silt and clay with lenses of metamorphic channel gravel.[1,2]

The Fair Oaks Formation represents the part of the subsurface of McClellan which ranges from 75 to 275 feet below the surface elevation. This formation is composed of poorly bedded silts, clays and sands with occasional lenses of gravel, resembling the Victor Formation. Numerous beds of white to gray white tuff and tuffaceous silts distinguish this formation.[1,2]

The oldest and deepest formation for this discussion is the Mehrten, which extends from 275 to perhaps 1200 feet below the base. It is divisible into two different units - one composed of gray to black andesitic sands with interbedded blue to brown clay, and the other is a hard, gray tuff-breccia. The black sands are fairly soft and are well sorted. They were formed as fluvial deposits washed down from the mountain slopes. The tuff-breccia was derived from andesitic eruptions to the east in the Sierra Nevada.[1,2]

All three formations are characterized by weaving and discontinuous ancient river and stream beds consisting of gravels, sands, silts and clays of various densities. It is these past river beds that serve as the best groundwater acquifers. Wells at McClellan are designed to withdraw water from these older river beds in the Fair Oaks and Mehrten Formations.[1,2,3]

Groundwater is defined as subsurface water occurring in the zone of soil where all the openings between soil particles, also known as voids, are completely filled with water. This zone is called the zone of saturation and is located immediately below the zone of aeration where the voids are only partly to not at all filled with water. Below McClellan the zone of saturation begins at approximately 90 feet. This point, the top of the zone of saturation, is known as the water table.[3,4]



GEOLOGIC SECTIONS - SACRAMENTO COUNTY

FIGURE 4-1

An aquifer, which occurs at or below the water table, is a water saturated geologic unit that will yield water to wells or springs at a sufficient rate so that the wells or springs can serve as practical sources of water supply. However, only a relatively small percentage of the entire groundwater bearing soil under McClellan yields water at such a rate to be classified as acquifer.[2,3,4]

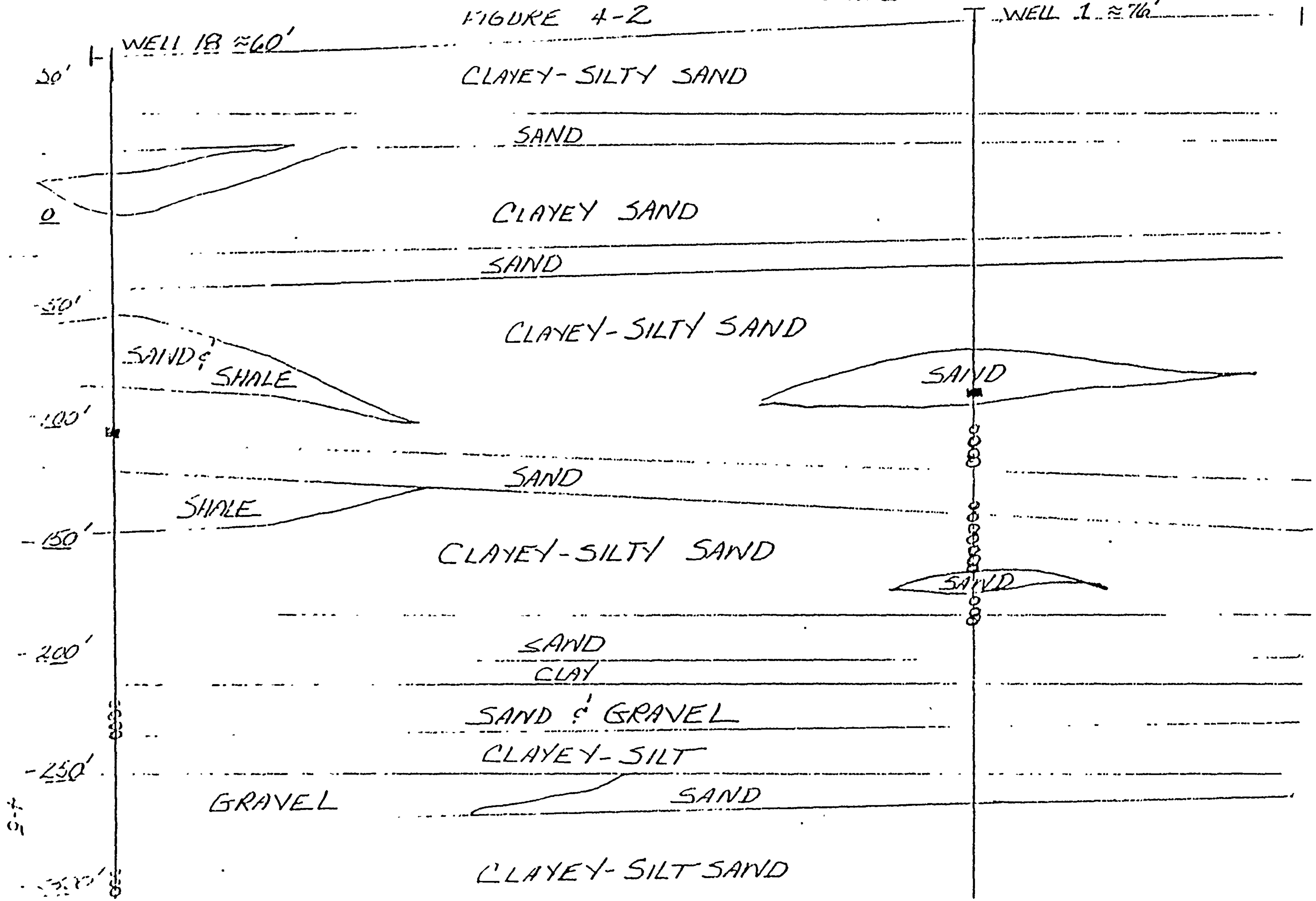
Finer materials such as silt or sand interbedded with silt or clay, may yield water to wells at very low rates but can transmit water between adjacent aquifers. These important groundwater storage units constitute a large percentage of McClellan's groundwater structure and are called aquitards. Making up a lesser degree of the groundwater soil mass under McClellan are areas composed of large amounts of clay which are relatively impermeable and are called aquicludes. These neither yield water to wells nor transmit appreciably from recharge sources. (A cross-section soil profile of McClellan AFB has been estimated from the best available information which includes numerous soil borings and well logs as well as consultation with appropriate literature. Figure 4-2 is such a profile. NOTE: Although relatively accurate data was used to initiate the development of this cross section a great deal of interpolation, extrapolation, and engineering judgement was used where data was void. The discontinuity of channels, extensive lenses, and interbedding of soils associated with the Victor and Fair Oaks Formations complicates any such estimations and should be considered only one possibility.) [2,3,4]

Recharging of McClellan's underlining water supply comes from three sources: aquifer recharge at the origin, in this case the mountains and foothills; infiltration of precipitation or irrigation through the zone of aeration; and finally, percolation of streamflow into the underlying and generally permeable soils down to the water table. Of the three the latter is by far the greatest contributor. Impermeable and steep surface conditions in the mountains and foothills force water to flow in stream and rivers to the valley rather than percolate to groundwater. The vertical resistance to water flow or impermeability of the Victor and Fair Oaks Formations restrict infiltration of precipitation or irrigation to underlying stratas.[1,2,3]

Although we know these formations hinder vertical flows, the time required to travel through the unsaturated zone to the distant water table is unknown. Variation in soil types and structure preclude the use of any one standard. However, there have been actual field measurements that offer a means of estimation. In the Mendota area (in the San Joaquin Valley), it was observed water traveled 128 feet in six months and 150 feet in 15 months. The California Department of Water Resources indicated infiltration time to reach water tables within Sacramento County alone vary considerably.[2]

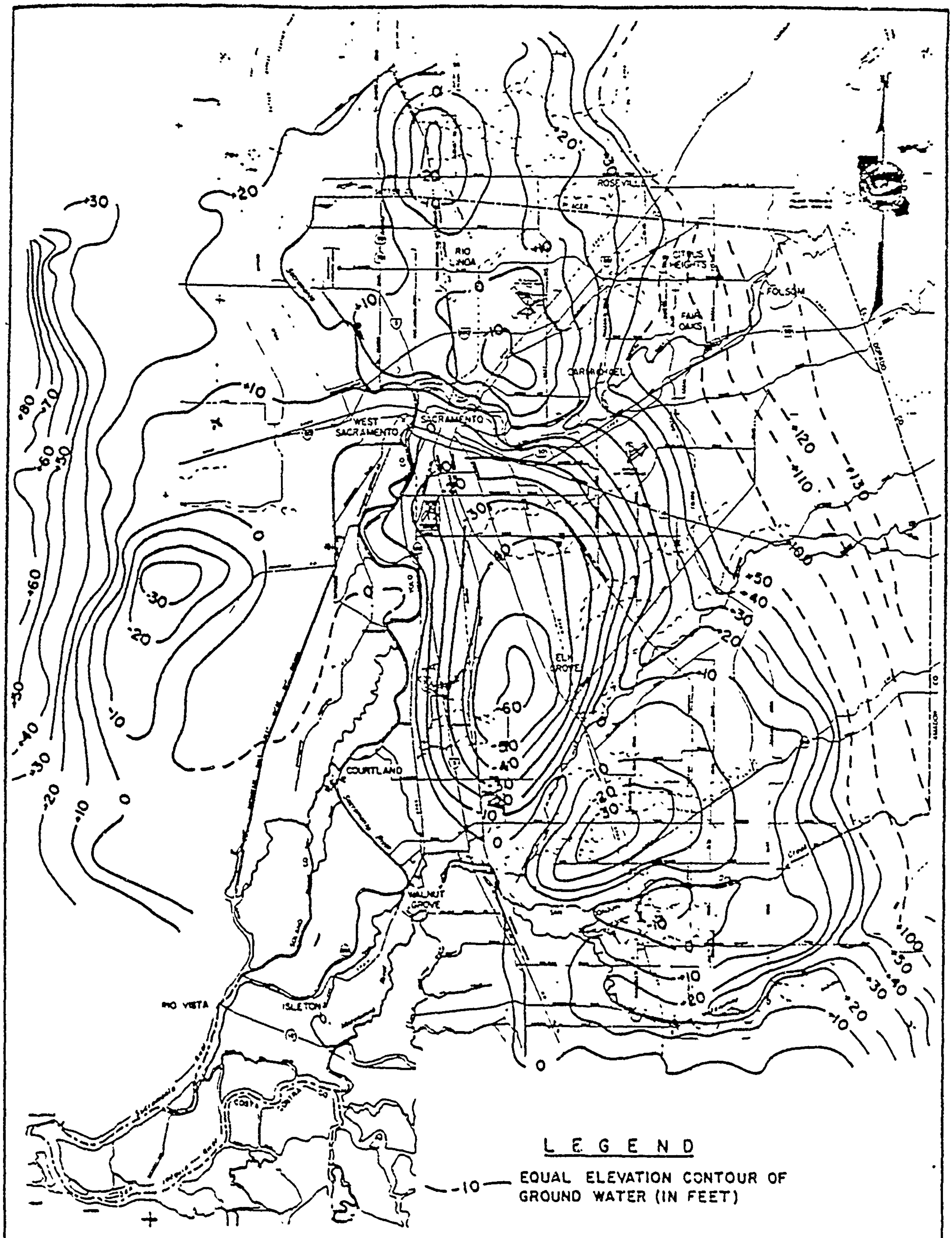
Direction of groundwater flow depends primarily upon variation of water table levels and soil types. Groundwater will flow in the direction of the downward gradient of the water table. A map of such gradients for Sacramento County is included as Figure 4-3 and indicates that the direction of flow under McClellan AFB is towards the southwest. Gradients always slope towards points of discharge. Discharge can be either natural, such as into a influent river (this is not the case for the Sacramento area where the rivers are for the most part effluent, meaning they act as points of recharge rather than discharge for groundwater), or man induced, such as pumping for industrial and irrigation purposes. This is the prominent force in the development of groundwater gradients in the McClellan area. While a general southwesterly flow is predicted for McClellan based on area groundwater gradients, localized variation can and certainly do occur dependent upon proximities to active wells.[2,3,4]

... PROFILE ESTIMATION FOR MCCLELLAN AFB
FIGURE 4-2



4-5

FIGURE 4-3



*CONTOURS OF EQUAL ELEVATION OF GROUND WATER, SPRING 1968

*Source: Department of Water Resources Bulletin No. 118-3, "Evaluation of Groundwater Resources, Sacramento County", July 1974

When pumping is first begun, the water level in the vicinity of the pumped well is lowered. The amount it drops is known as drawdown. The greatest amount of drawdown is at the point of the well and lessens in all direction the greater the distance from the well until finally at some point the water level is essentially unaffected. What is produced from the pumping is called a cone of depression. The size and shape of the cone (i.e., the depth of drawdown and the distance of its effect) varies and is dependent upon pumping rate, length of time pumped, waterbearing characteristics of soil formations, and proximity to other points of discharge. The variability of these parameters make cone of depression predictions very difficult, for instance, the drawdown may be 20 feet in one well with corresponding cone radius of 10,000 feet, while in a nearby well the drawdown may be only 3 feet but have a cone radius of 40,000 feet. The difference of elevation or head created by this pumping causes water in and near the cone of depression to flow towards the discharge point even if it might otherwise be against the general water flow direction of the area. These cone variations make water flow determination very difficult in highly pumped areas. A typical drawdown at McClellan for a pumping rate of 600 to 700 gallons per minute is 20 feet. This equates to what is known as the specific capacity of the well of 30 to 35 gallons per minute per foot.[3,4,5]

Rate of flow varies based on the steepness of groundwater gradients and the permeability of the transmitting aquifer. The rate for water underlying McClellan could vary from less than one foot per year to perhaps 30 feet per year based on an estimated gradient and dependent on the aquifer soil type. A reasonable expected average considering the predominent soil types and densities might be in the realm of two or three feet per year.[2,3,4,5]

For a more detailed discussion of either the geology or geohydrology of California and the Sacramento Valley or of geology and geohydrology in general, the reader is referred to the many very good references listed in the bibliography to this Appendix. Further data on the groundwater underlying McClellan AFB can be found in the text of this report or its appendixes.

BIBLIOGRAPHY

1. State of California, Department of Water Resources, "Evaluation of Ground Water Resources: Sacramento Valley.," Bulletin 118-6, August 1978.

2. State of California, Department of Water Resources, "Evaluation of Ground Water Resources: Sacramento County," Bulletin 118-3, July 1974 (reprinted April 1980).

3. McClellan AFB Environmental Planning Office, "Soil Boring Logs," "Well Logs," and "Well Data," Office Files.

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5. T.W. Lambe, and R.V. Whitman, "Soil Mechanics," Library of Congress Catalog Number: 68-30915, 1969.

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7. U.S. Environmental Protection Agency, "Landfill Disposal of Hazardous Wastes: A Review of Literature and Known Approaches," EPA/530/SW-165, September 1975.

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9. State of California, Department of Water Resources, "California's Ground Water," Bulletin 118, September 1975.

10. H.R. Cedergren, "Seepage, Drainage, and Flow Nets," Second Edition, Library of Congress Catalog Number: 77-3664, 1967 and 1977.

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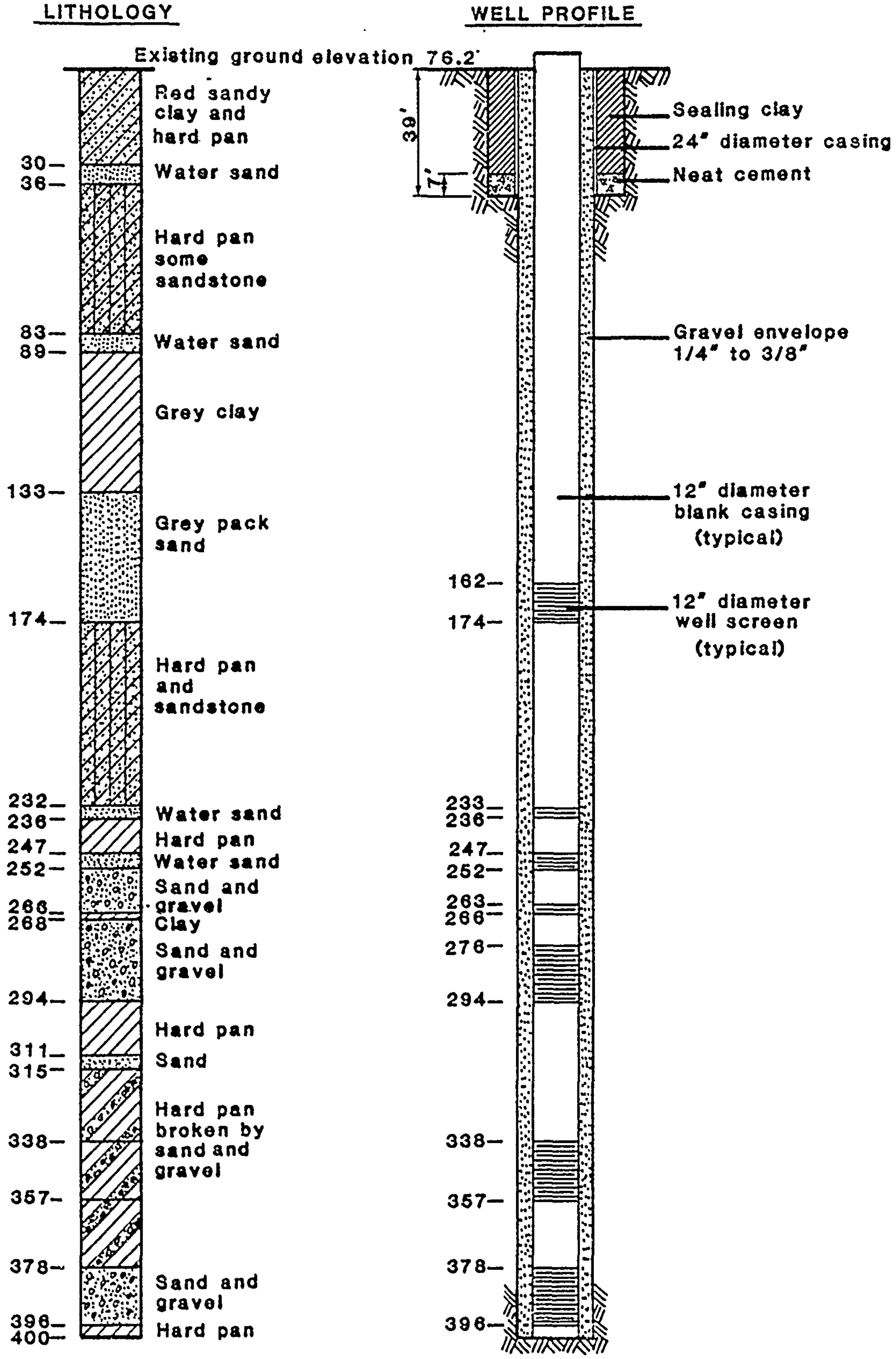
APPENDIX D

DETAILS OF BASE WELL CONSTRUCTION

AND WELL PRODUCTION

Luhdorff & Scalmanini



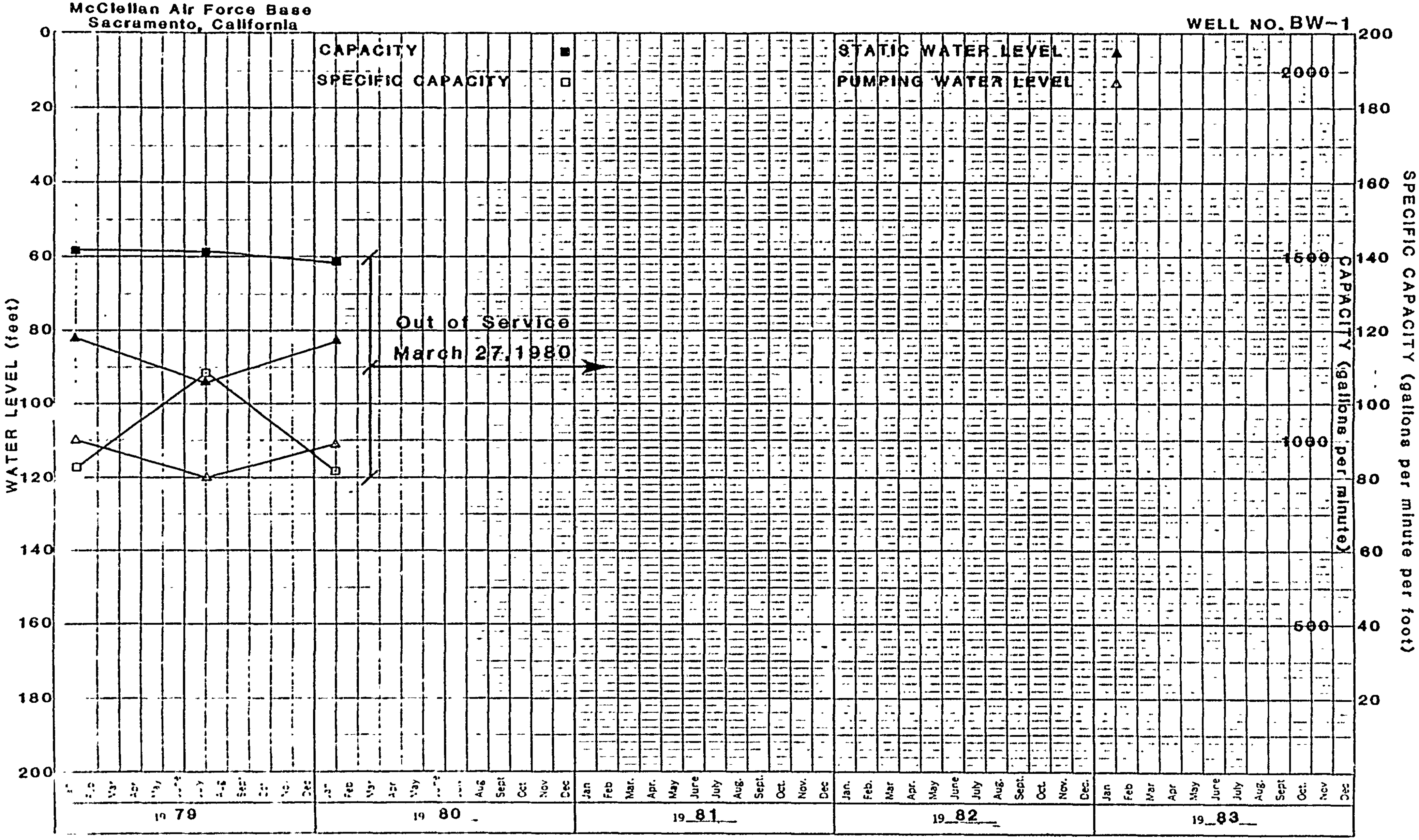
Vertical Scale 1"= 50'

Lithology and
Well Construction Profile
Of Base Production Well No.1

DEPARTMENT OF THE AIR FORCE
SACRAMENTO AIR LOGISTICS CENTER
McCLELLAN AIR FORCE BASE
CALIFORNIA 95652

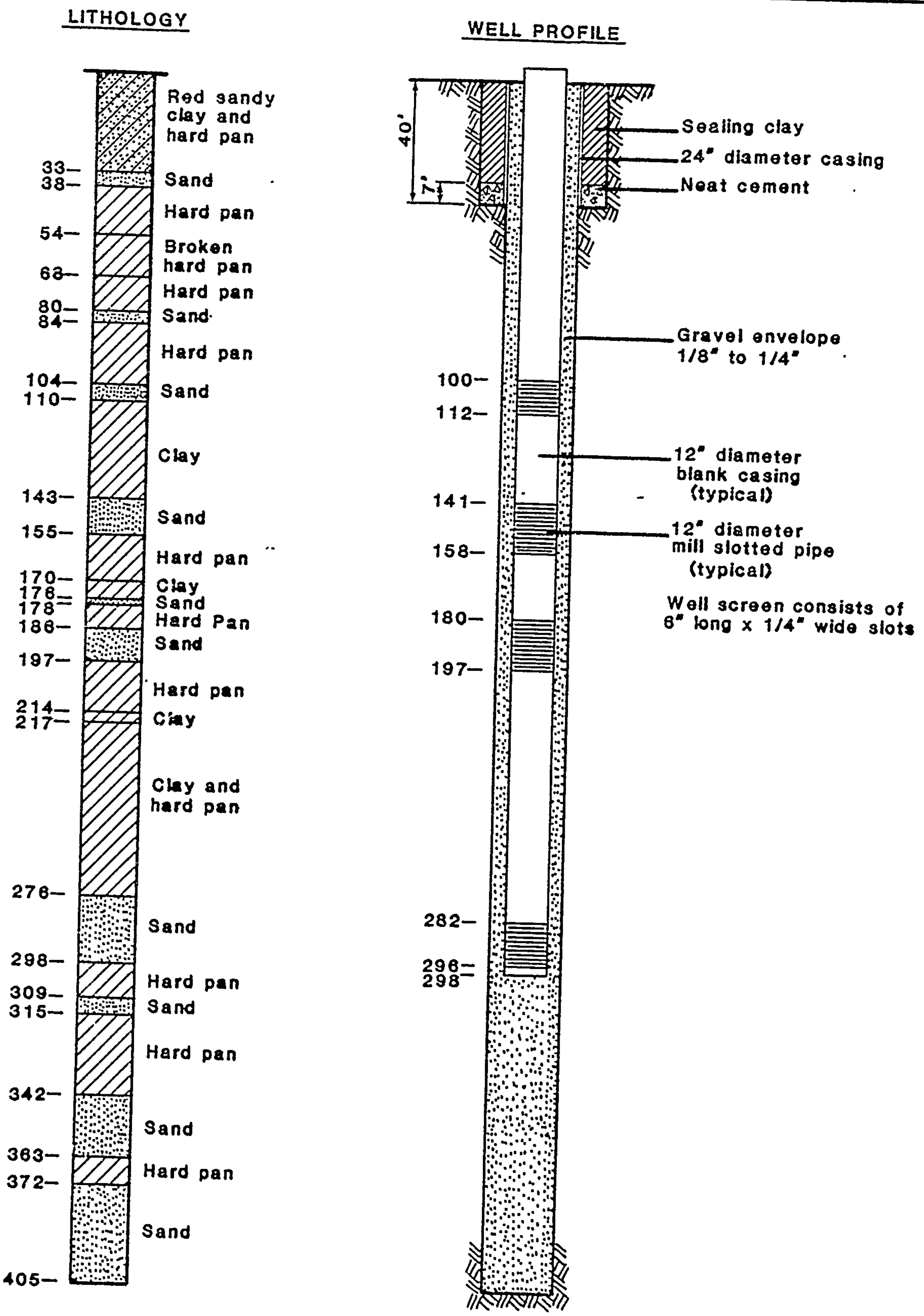
K+E 5 YEARS BY MONTHS X 100 DIVISIONS
KEUFFEL & ESSER CO. MADE IN USA

HISTORICAL WELL PROFILE



LUHDORFF AND SCALMANINI
Consulting Engineers

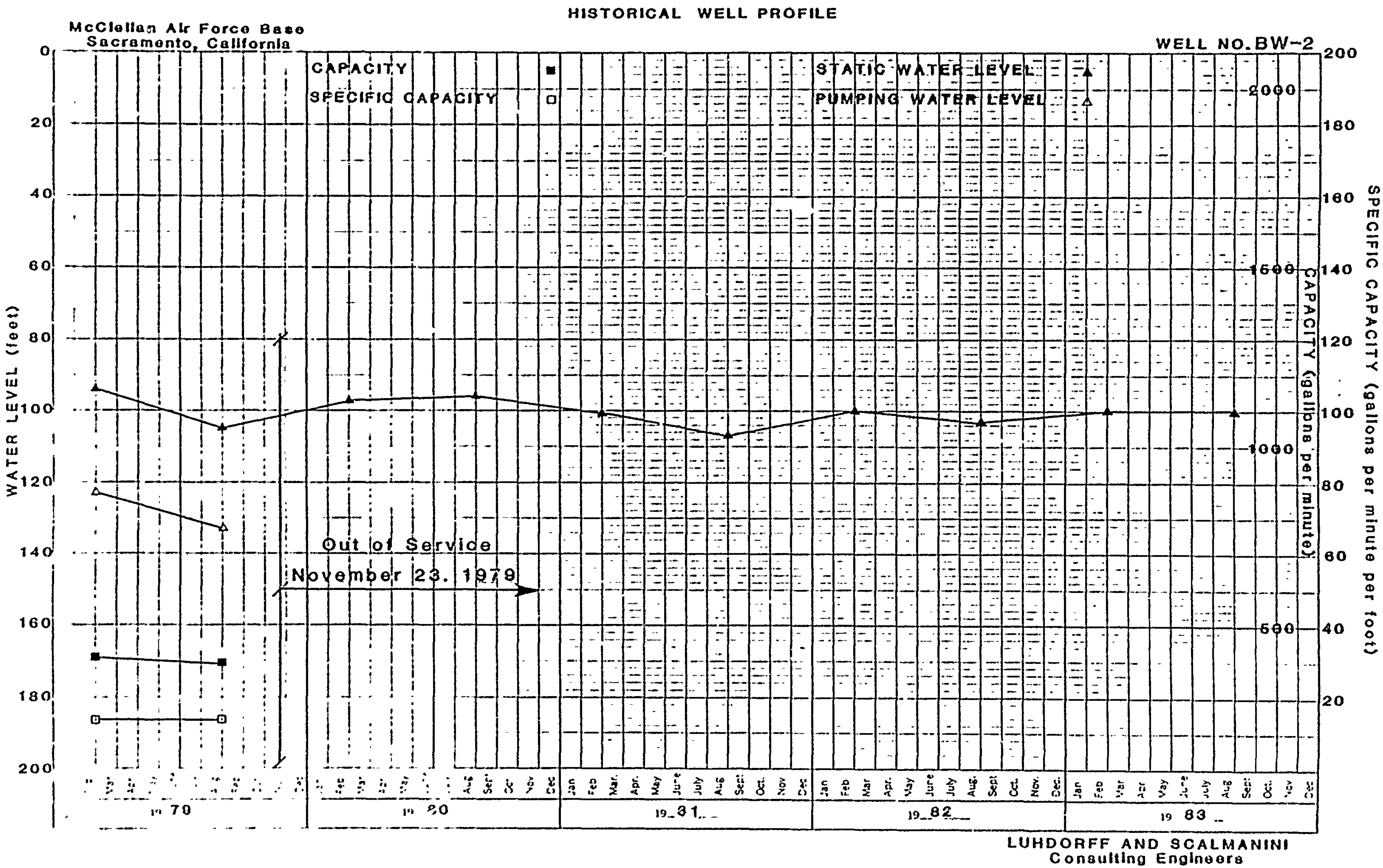
Luhdorff & Scalmanini



Vertical Scale 1"=50'

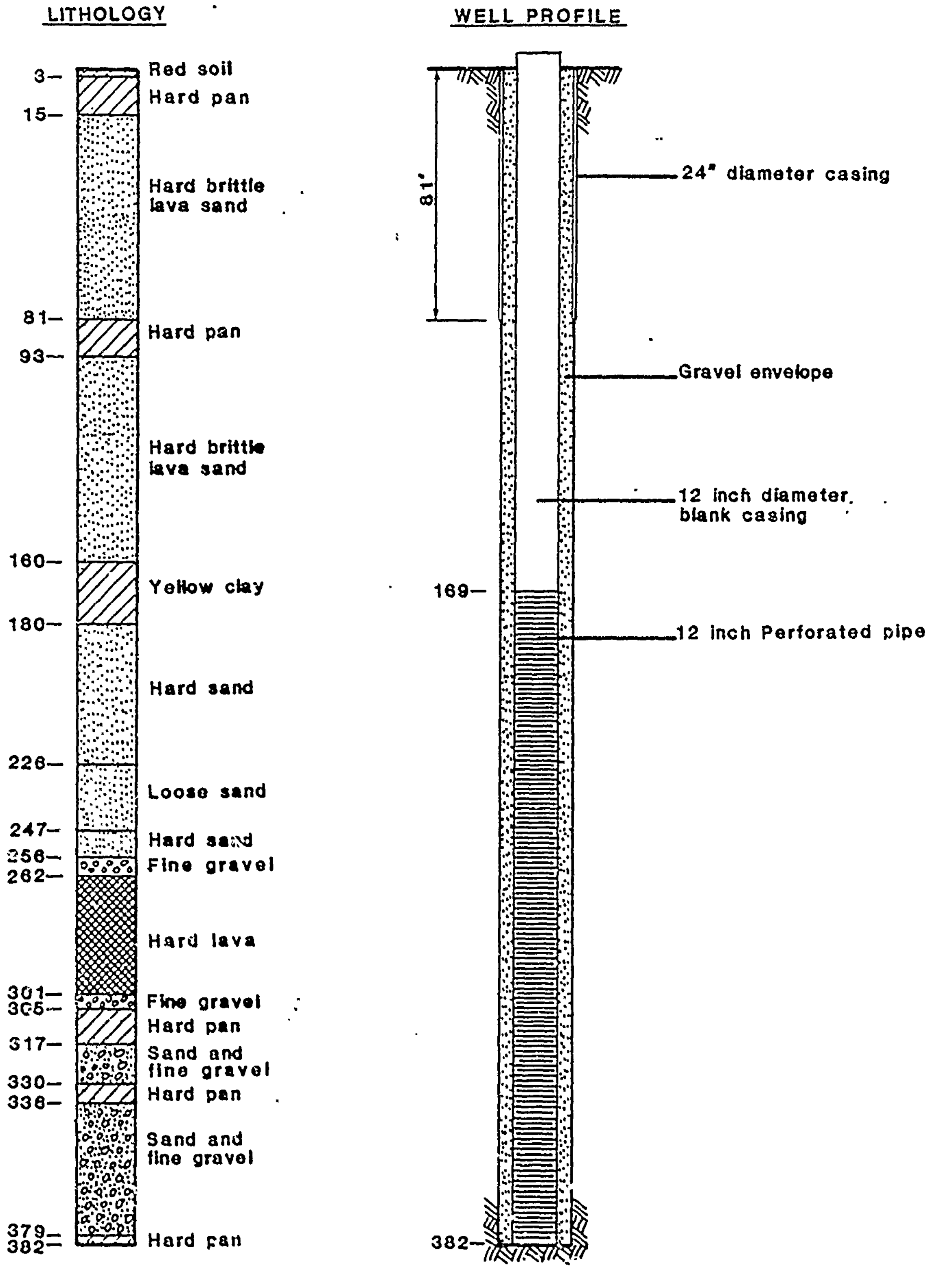
Lithology and
Well Construction Profile
Of Base Production Well No.2

DEPARTMENT OF THE AIR FORCE
SACRAMENTO AIR LOGISTICS CENTER
McCLELLAN AIR FORCE BASE
CALIFORNIA 95652



HISTORICAL WELL PROFILE
McClellan Air Force Base
Sacramento, California
WELL NO. BW-2
CAPACITY
SPECIFIC CAPACITY
STATIC WATER LEVEL
PUMPING WATER LEVEL
Out of Service
November 23, 1979
WATER LEVEL (feet)
0
20
40
60
80
100
120
140
160
180
200
SPECIFIC CAPACITY (gallons per minute per foot)
CAPACITY (gallons per minute)
2000
1500
1000
500
Jan Feb Mar. Apr. May June July Aug. Sept Oct. Nov. Dec.
19 79
19 80
19 81
19 82
19 83
LUHDORFF AND SCALMANINI
Consulting Engineers

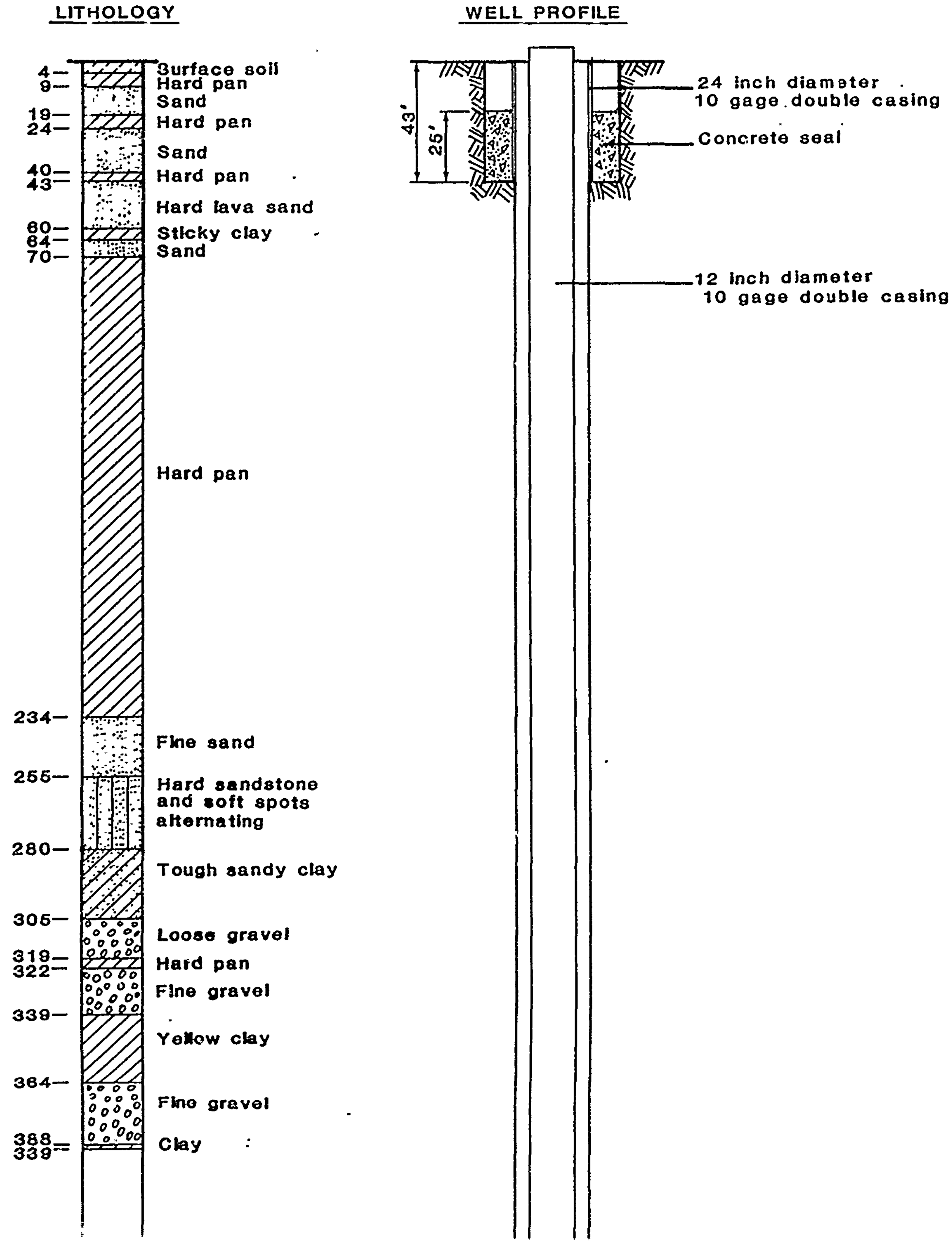
Luhdorff & Scalmanini



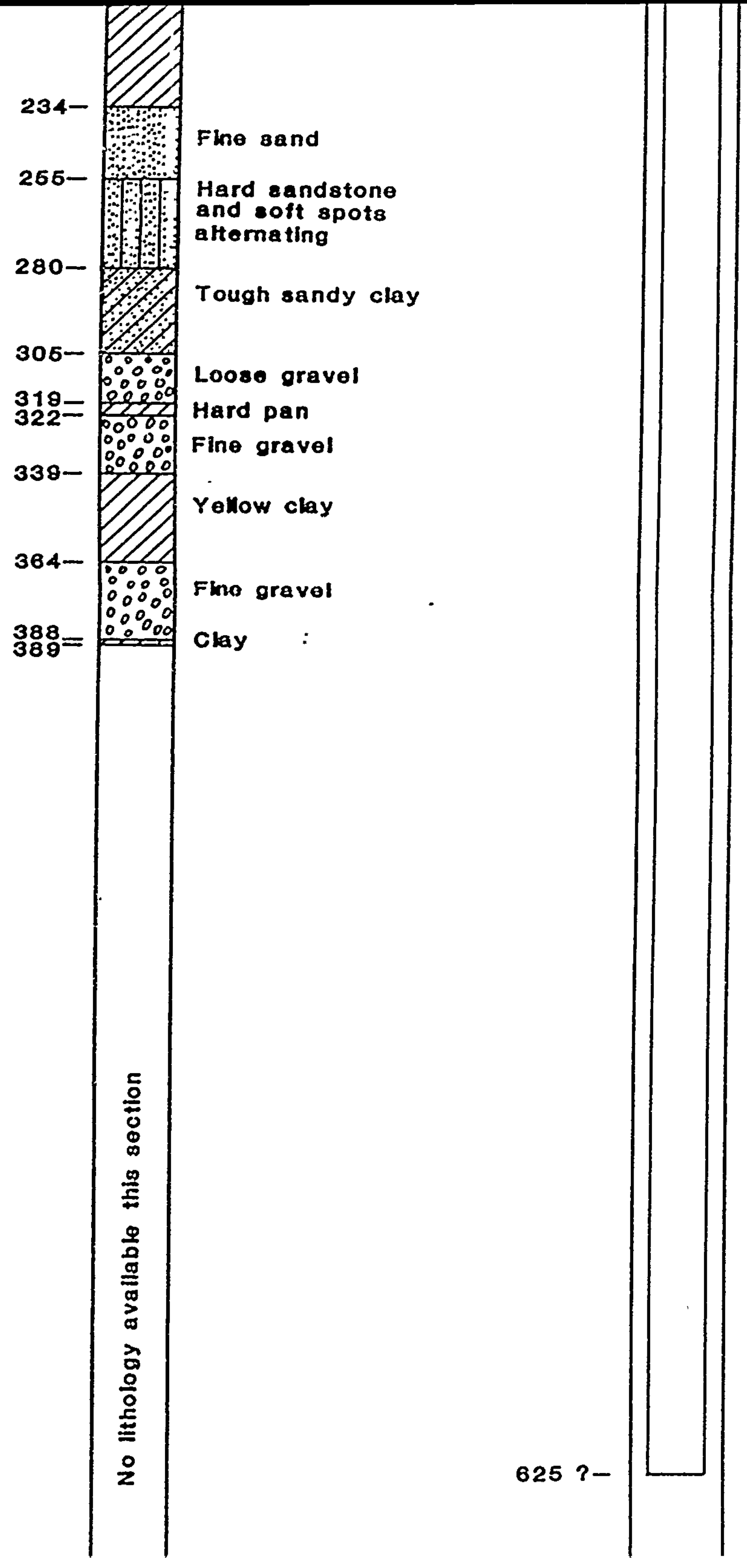
Vertical Scale 1"= 50'

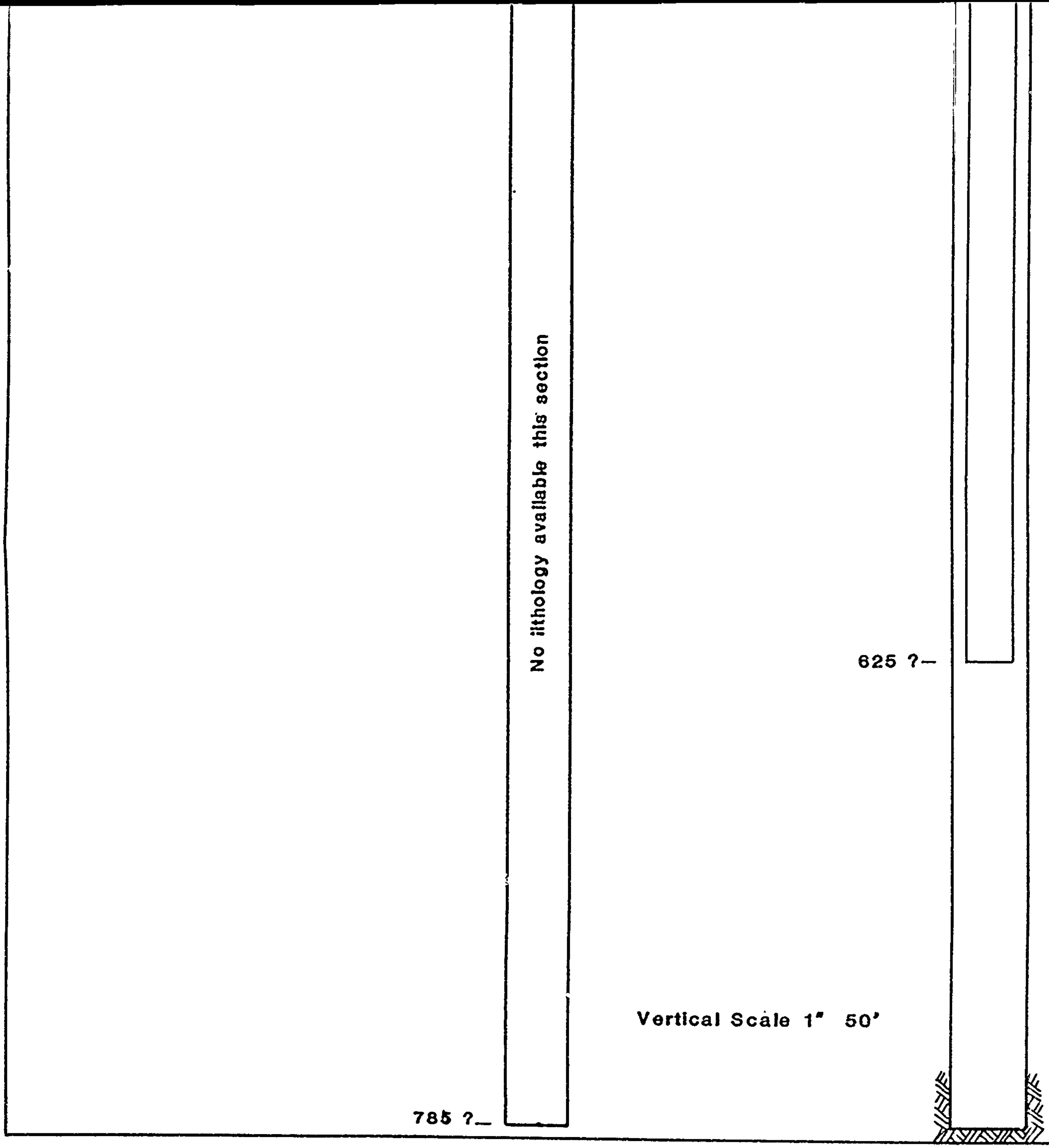
Lithology and
Well Construction Profile
Of Base Production Well No.4

DEPARTMENT OF THE AIR FORCE
SACRAMENTO AIR LOGISTICS CENTER
McCLELLAN AIR FORCE BASE
CALIFORNIA 95652



LITHOLOGY
WELL PROFILE
4—
9—
19—
24—
40—
43—
60—
64—
70—
234—
255—
280—
305—
319—
322—
339—
364—
388—
339—
Surface soil
Hard pan
Sand
Hard pan
Sand
Hard pan
Hard lava sand
Sticky clay
Sand
Hard pan
Fine sand
Hard sandstone and soft spots alternating
Tough sandy clay
Loose gravel
Hard pan
Fine gravel
Yellow clay
Fine gravel
Clay
43'
25'
24 inch diameter 10 gage double casing
Concrete seal
12 inch diameter 10 gage double casing


234—
Fine sand
255—
Hard sandstone and soft spots alternating
280—
Tough sandy clay
305—
Loose gravel
319—
Hard pan
322—
Fine gravel
339—
Yellow clay
364—
Fine gravel
388—
Clay
389—
No lithology available this section
625 ?—

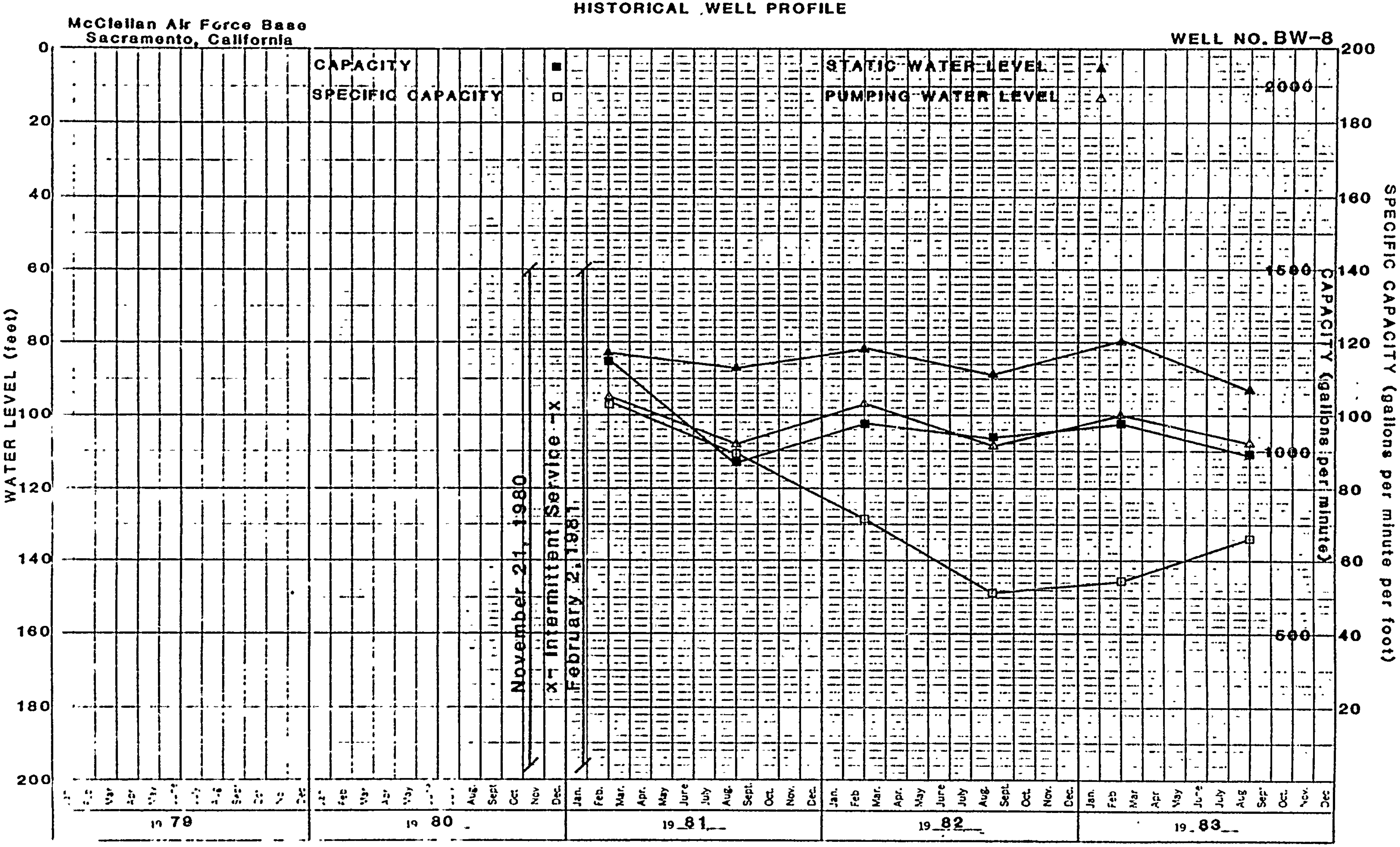


Lithology and
Well Construction Profile
Of Base Production Well No.8

DEPARTMENT OF THE AIR FORCE
SACRAMENTO AIR LOGISTICS CENTER
McCLELLAN AIR FORCE BASE
CALIFORNIA 95652

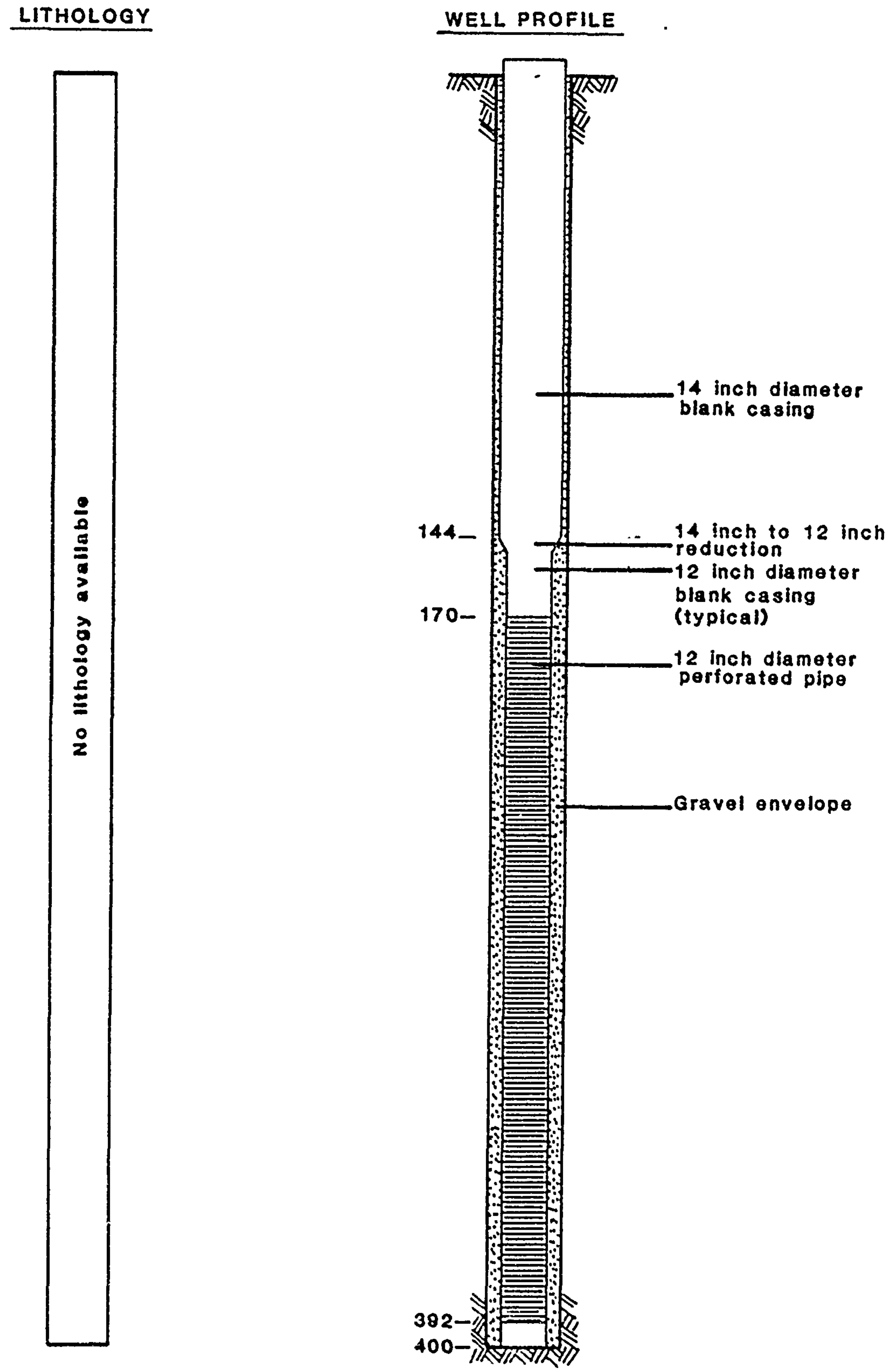
K&E 5 YEARS BY MONTHS X 100 DIVISIONS KEUFFEL & ESSER CO. MADE IN USA

HISTORICAL WELL PROFILE



LUHDORFF AND SCALMANINI
Consulting Engineers

Luhdorff & Scalmanini



Vertical Scale 1" = 50'

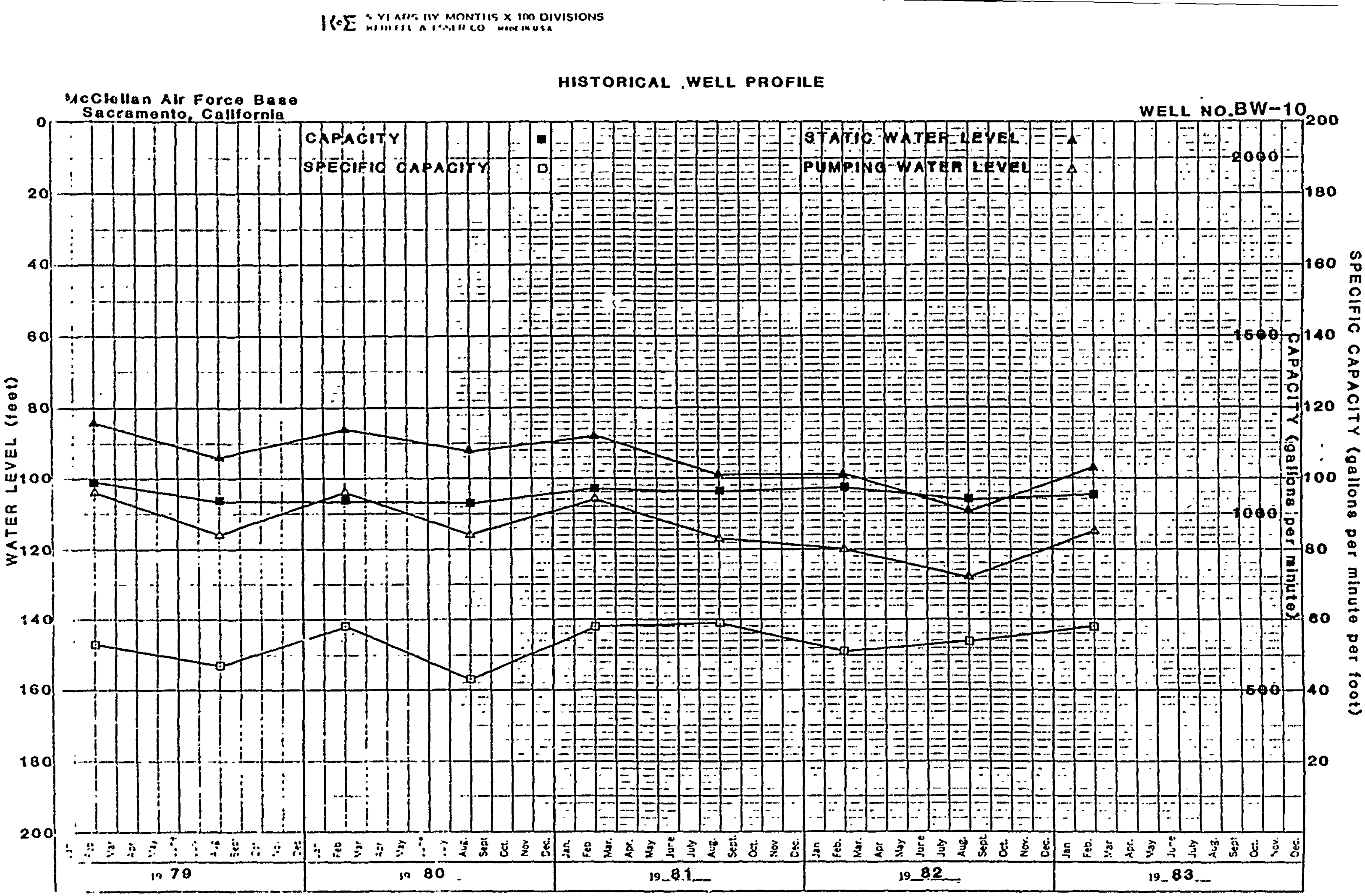
Lithology and
Well Construction Profile
Of Base Production Well No.10

DEPARTMENT OF THE AIR FORCE
SACRAMENTO AIR LOGISTICS CENTER
McCLELLAN AIR FORCE BASE
CALIFORNIA 95652

HISTORICAL WELL PROFILE

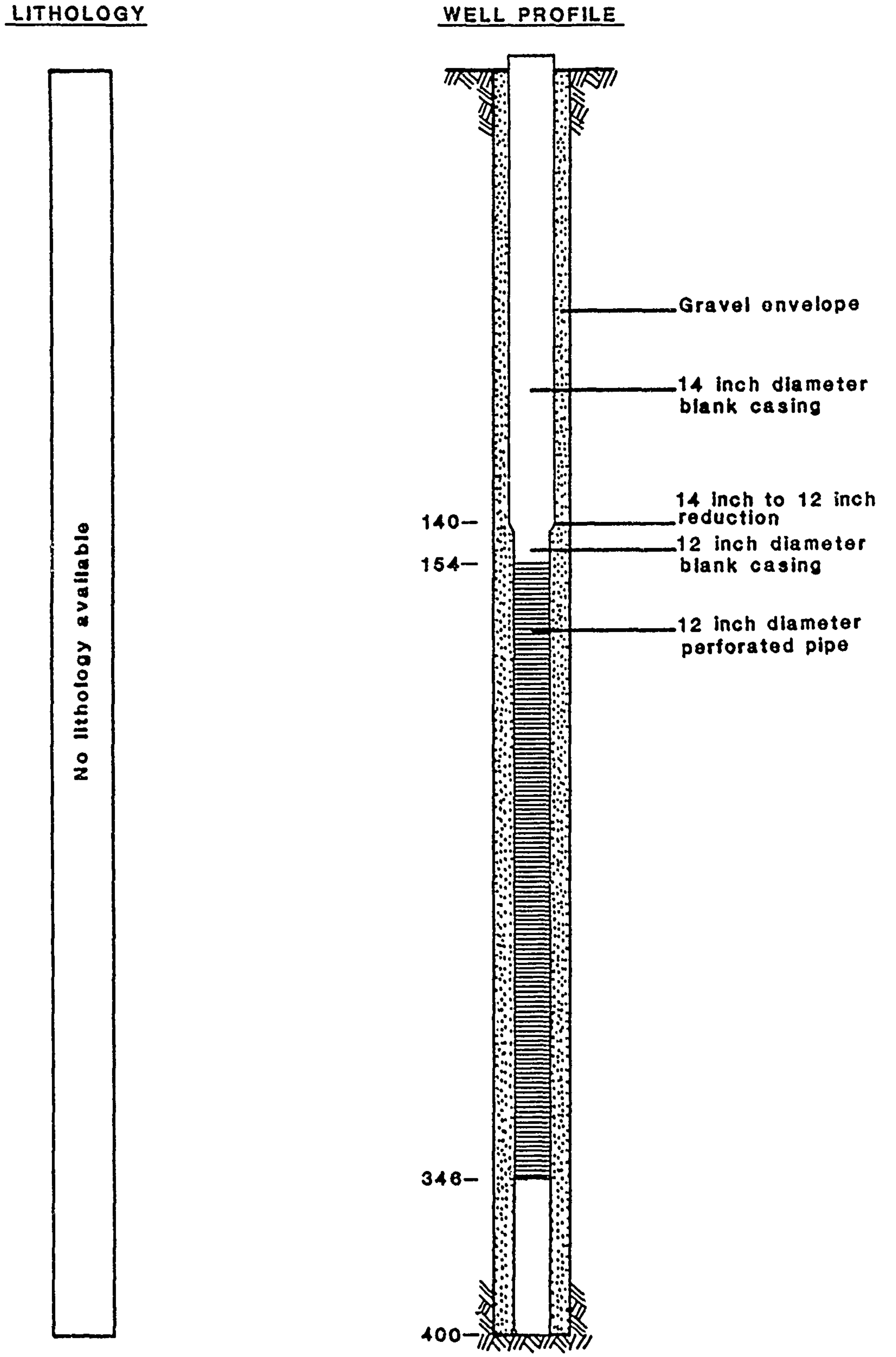
McClellan Air Force Base
Sacramento, California

WELL NO. BW-10



LUHDORFF AND SCALMANINI
Consulting Engineers

Luhdorff & Scalmanini



Vertical Scale 1" = 50'

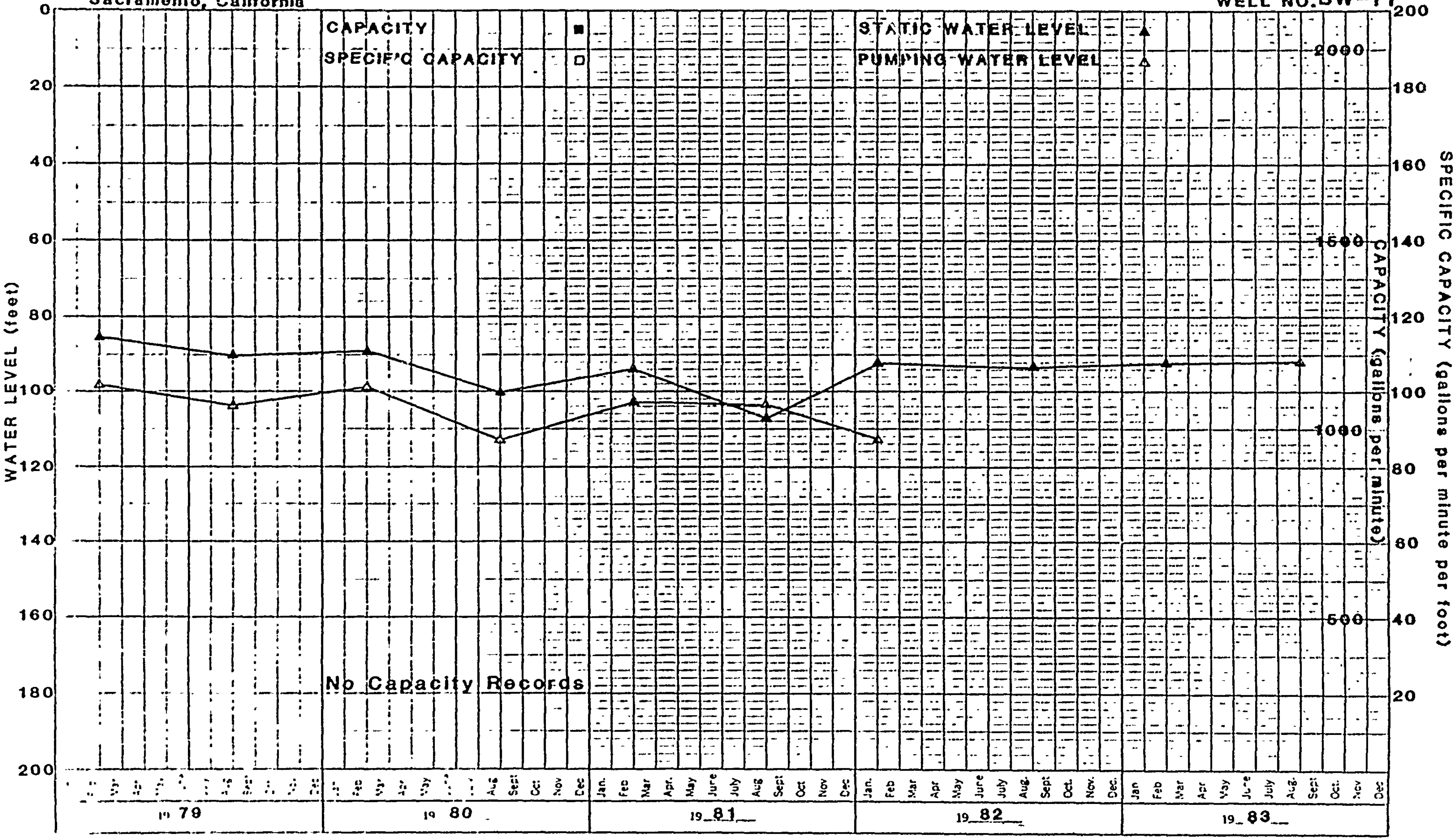
Lithology and
Well Construction Profile
Of Base Production Well No. 11

DEPARTMENT OF THE AIR FORCE
SACRAMENTO AIR LOGISTICS CENTER
McCLELLAN AIR FORCE BASE
CALIFORNIA 95652

HISTORICAL WELL PROFILE

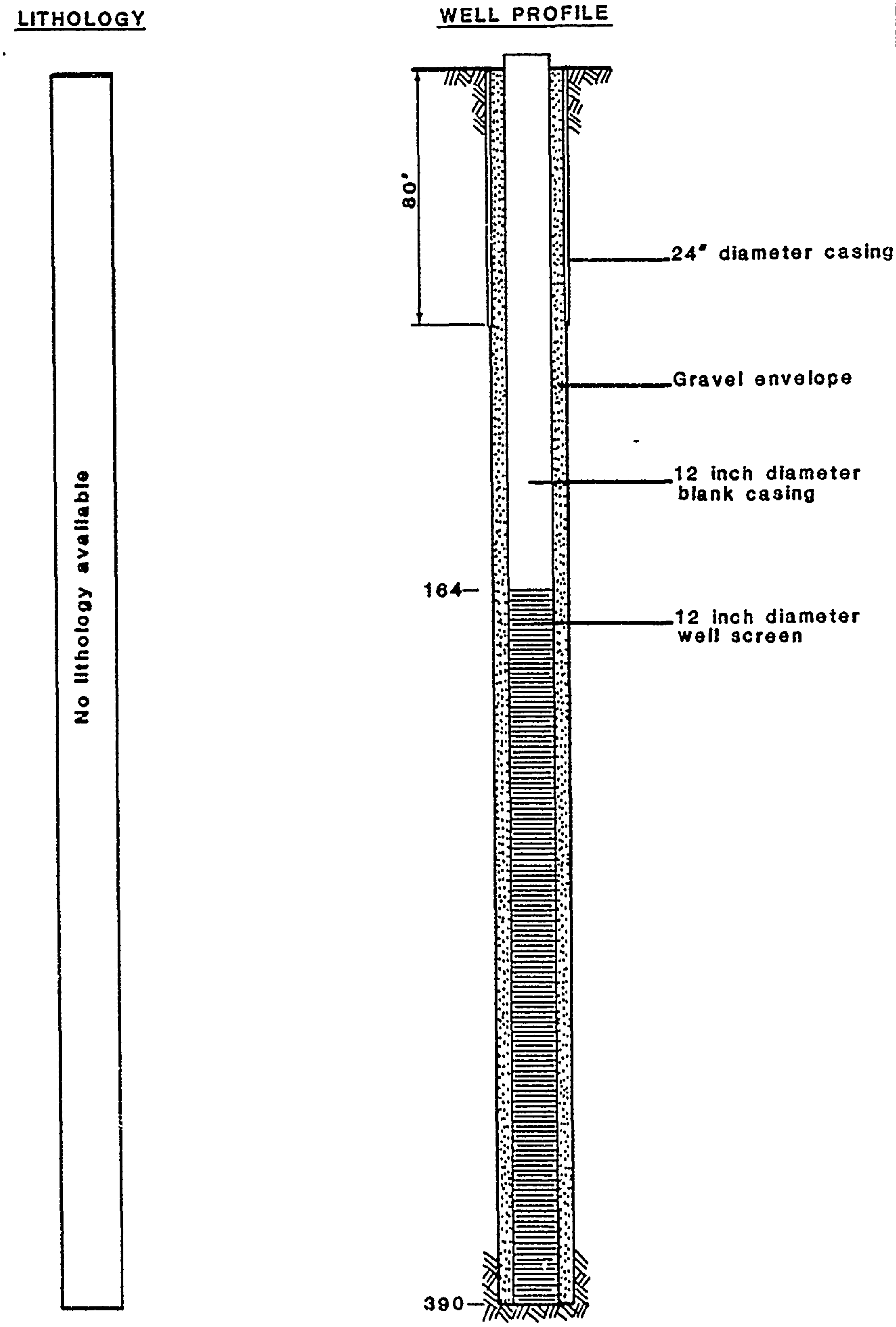
McClellan Air Force Base
Sacramento, California

WELL NO. BW-11



LUHDORFF AND SCALMANINI
Consulting Engineers

Luhdorff & Scalmanini



Vertical Scale 1"= 50'

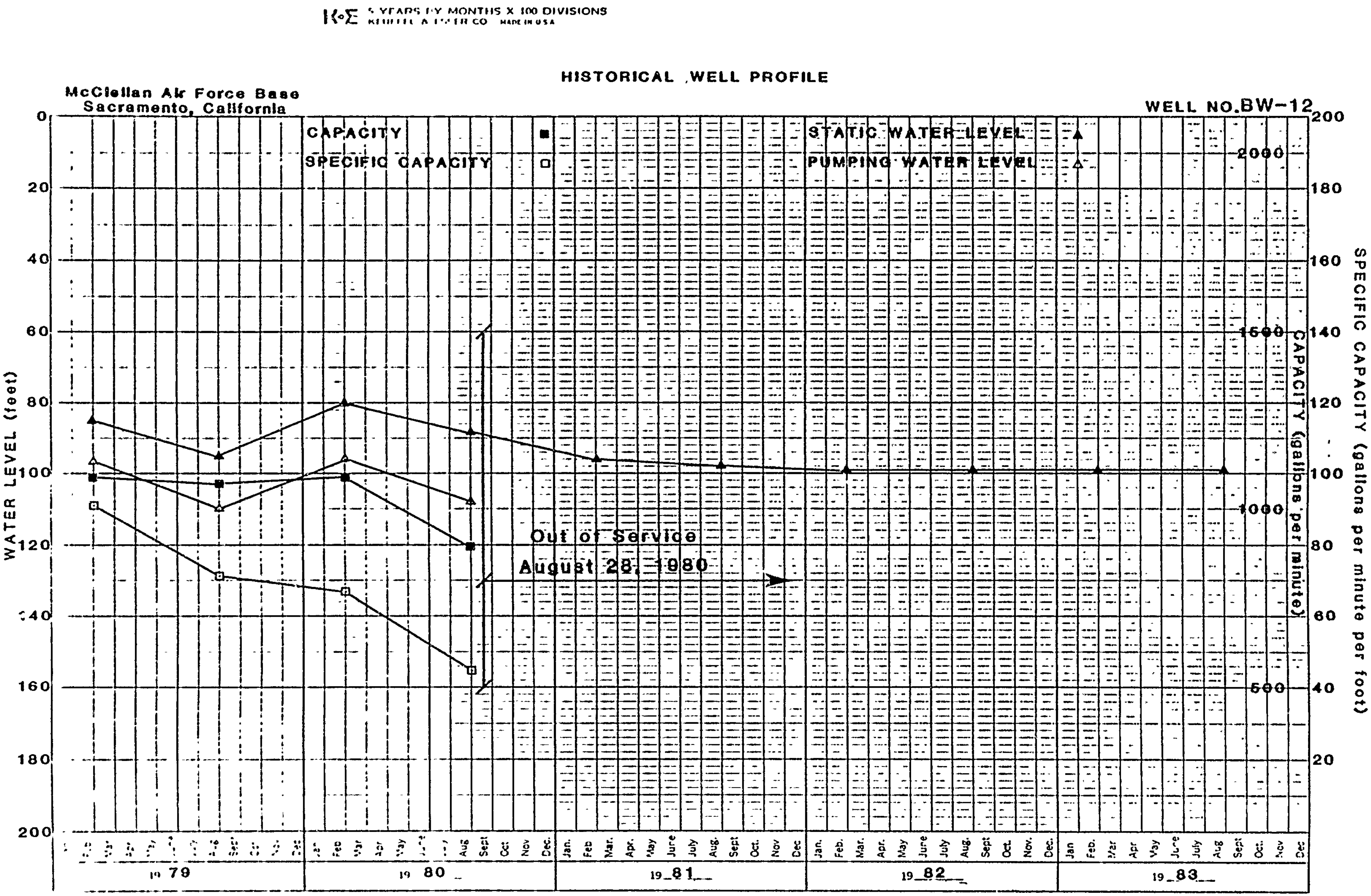
Lithology and
Well Construction Profile
Of Base Production Well No.12

DEPARTMENT OF THE AIR FORCE
SACRAMENTO AIR LOGISTICS CENTER
McCLELLAN AIR FORCE BASE
CALIFORNIA 95652

HISTORICAL WELL PROFILE

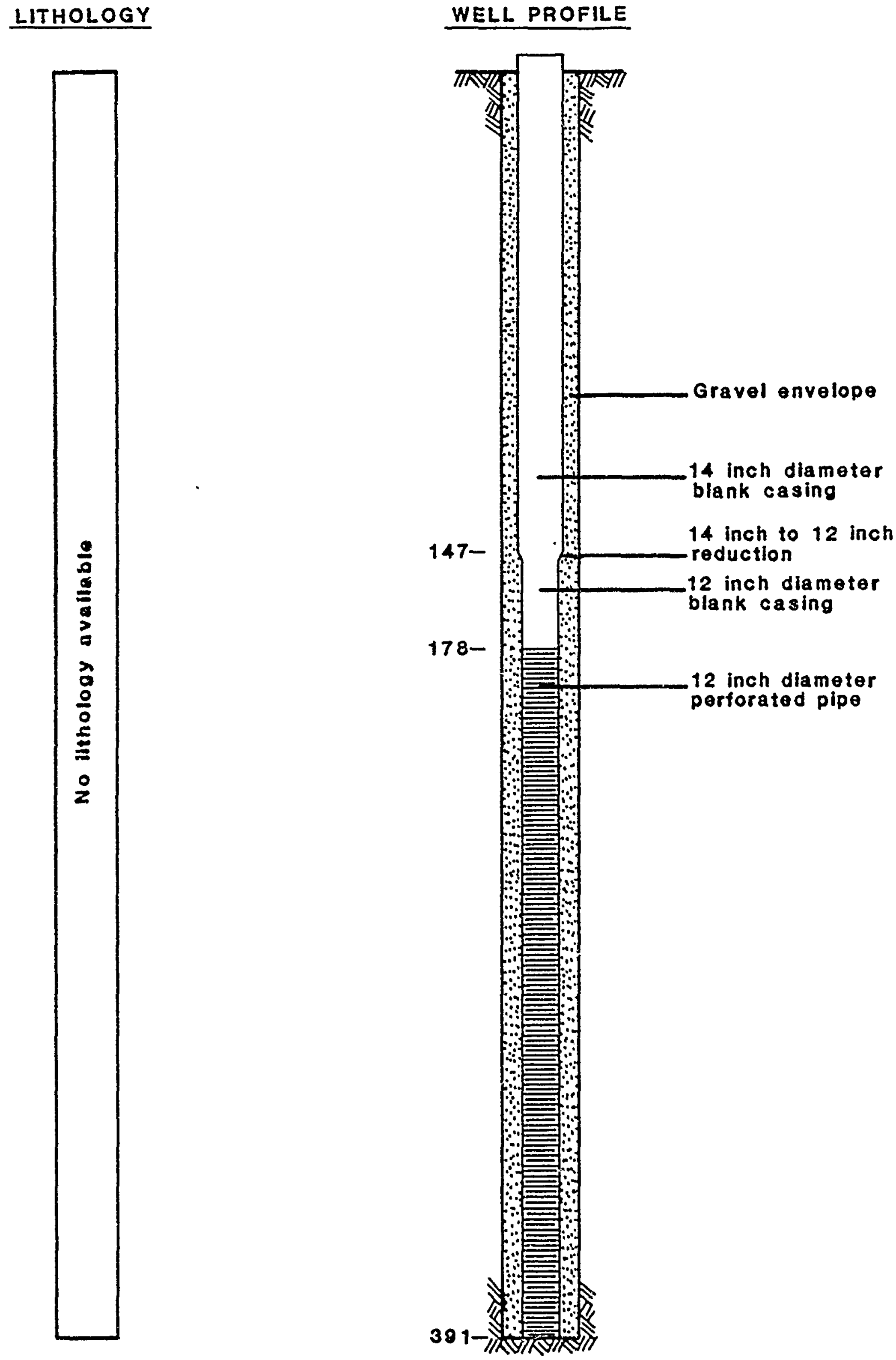
McClellan Air Force Base
Sacramento, California

WELL NO. BW-12



LUHDORFF AND SCALMANINI
Consulting Engineers

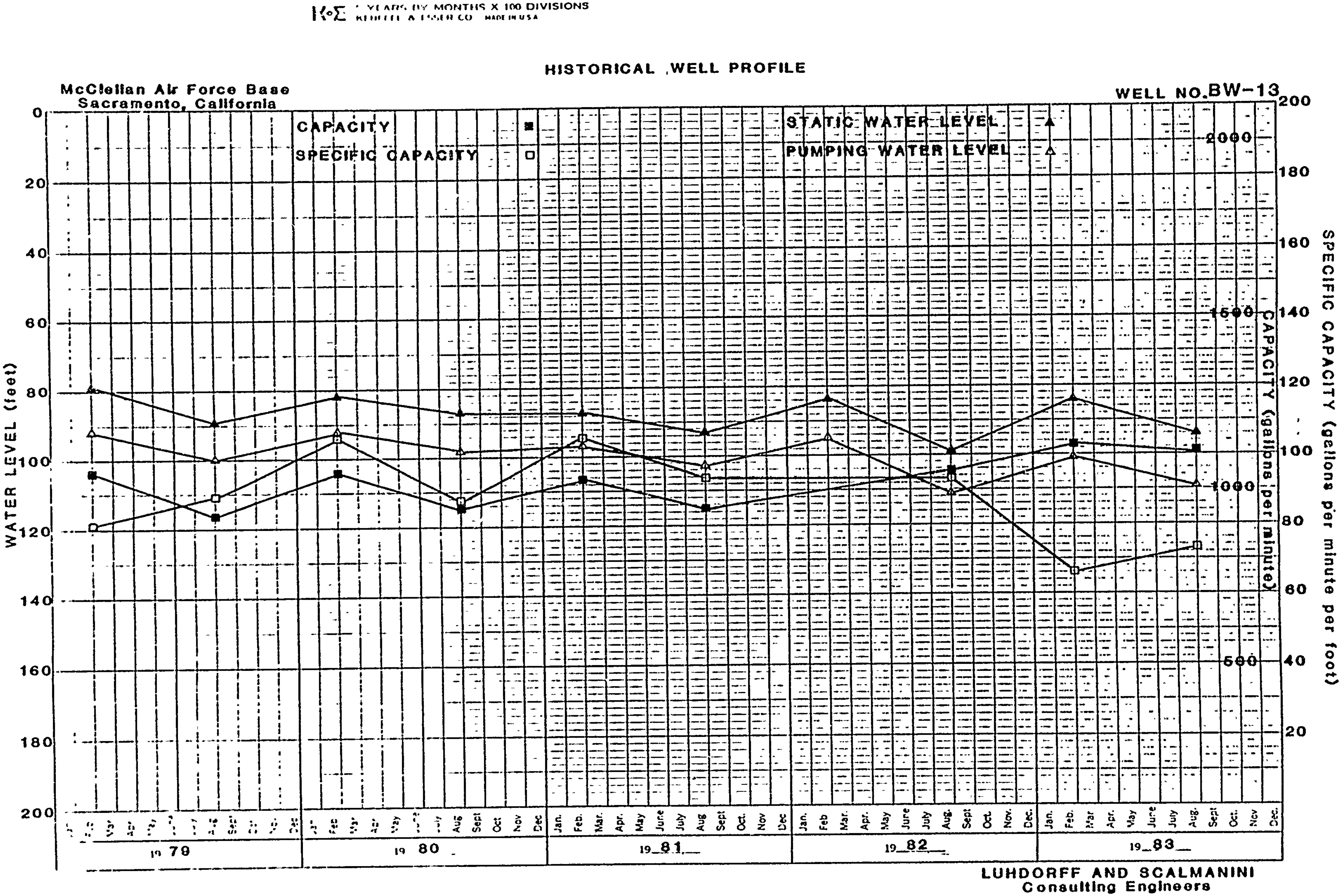
Luhdorff & Scalmanini

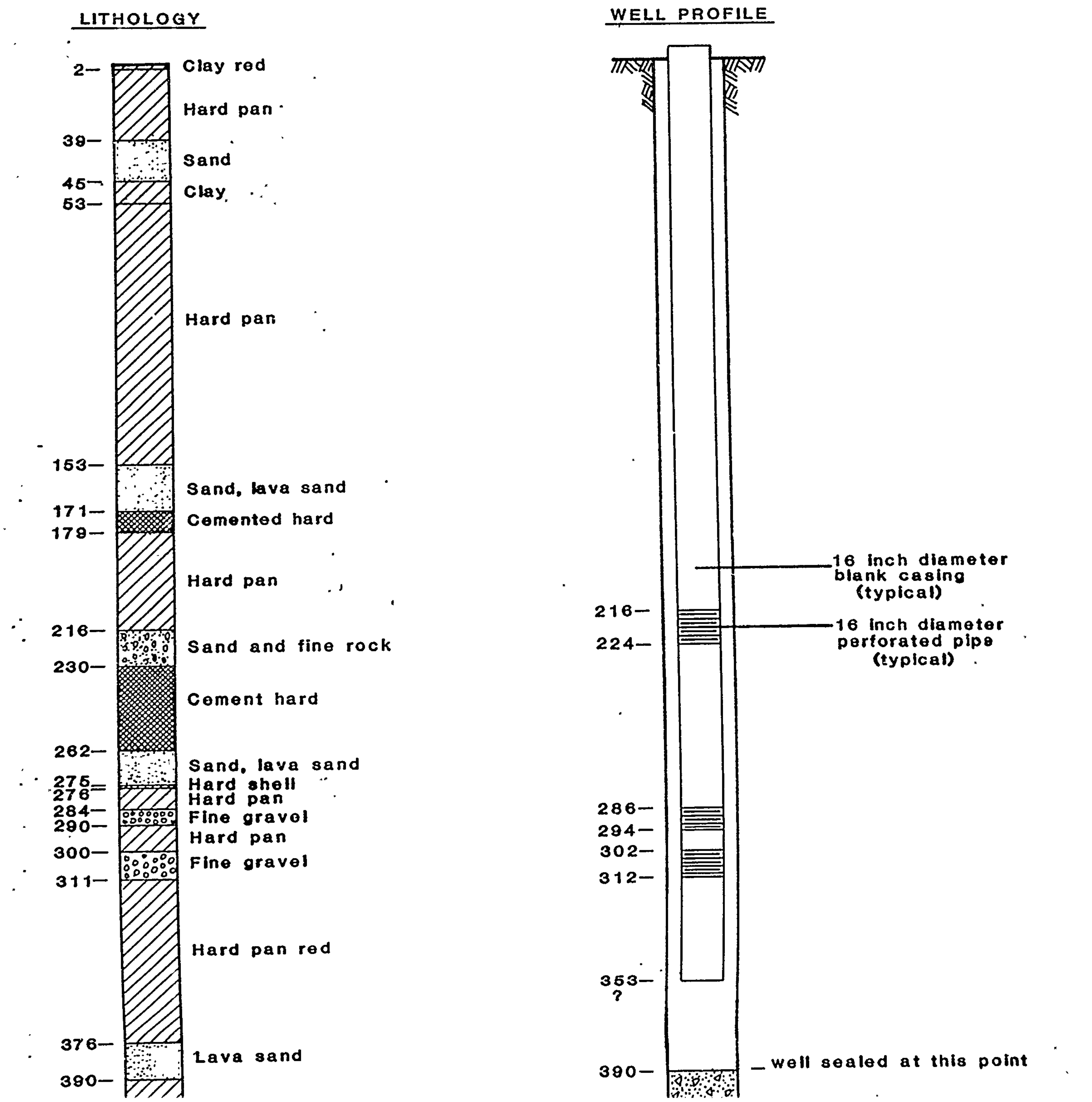


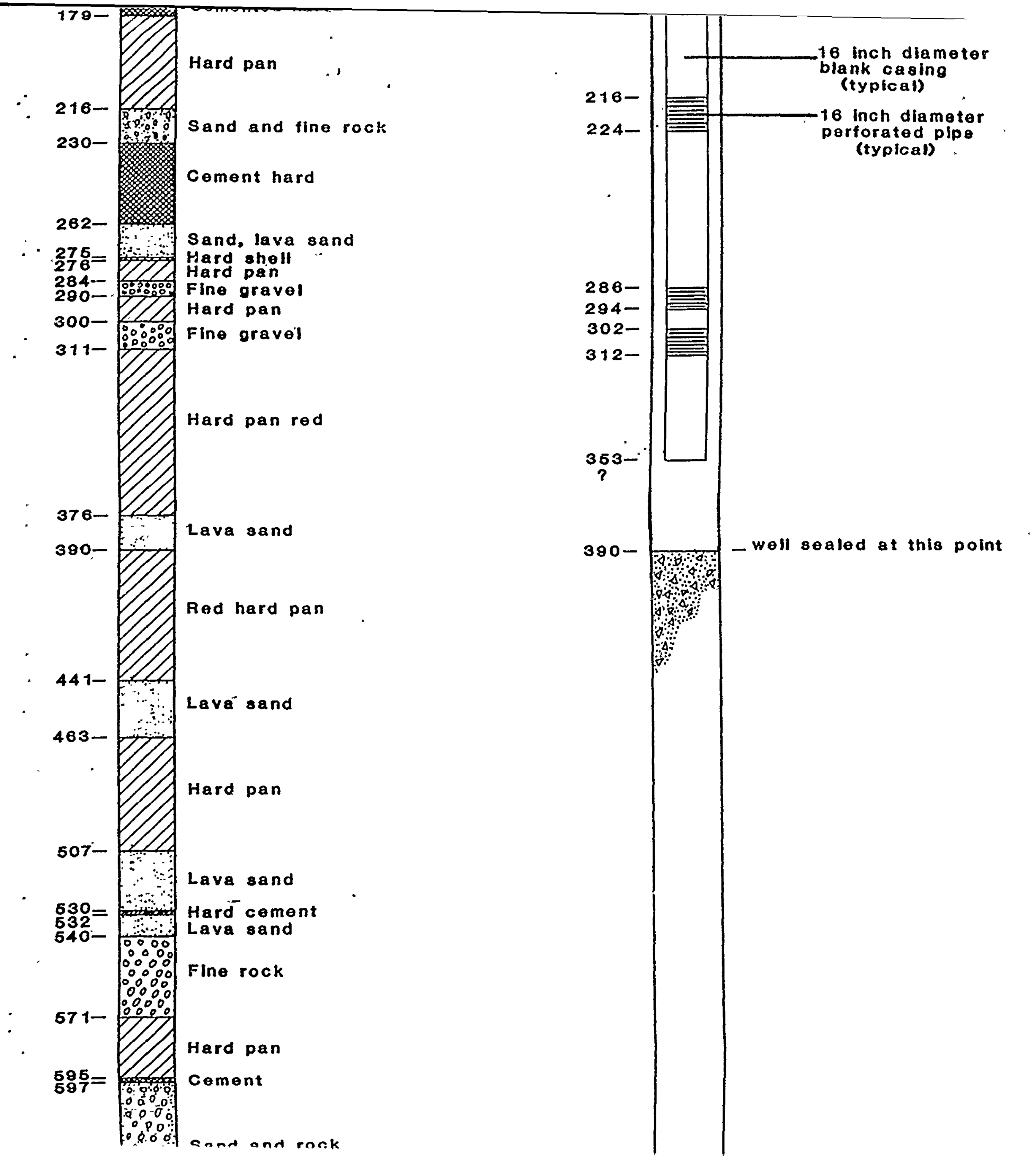
Vertical Scale 1" = 50'

Lithology and
Well Construction Profile
Of Base Production Well No.13

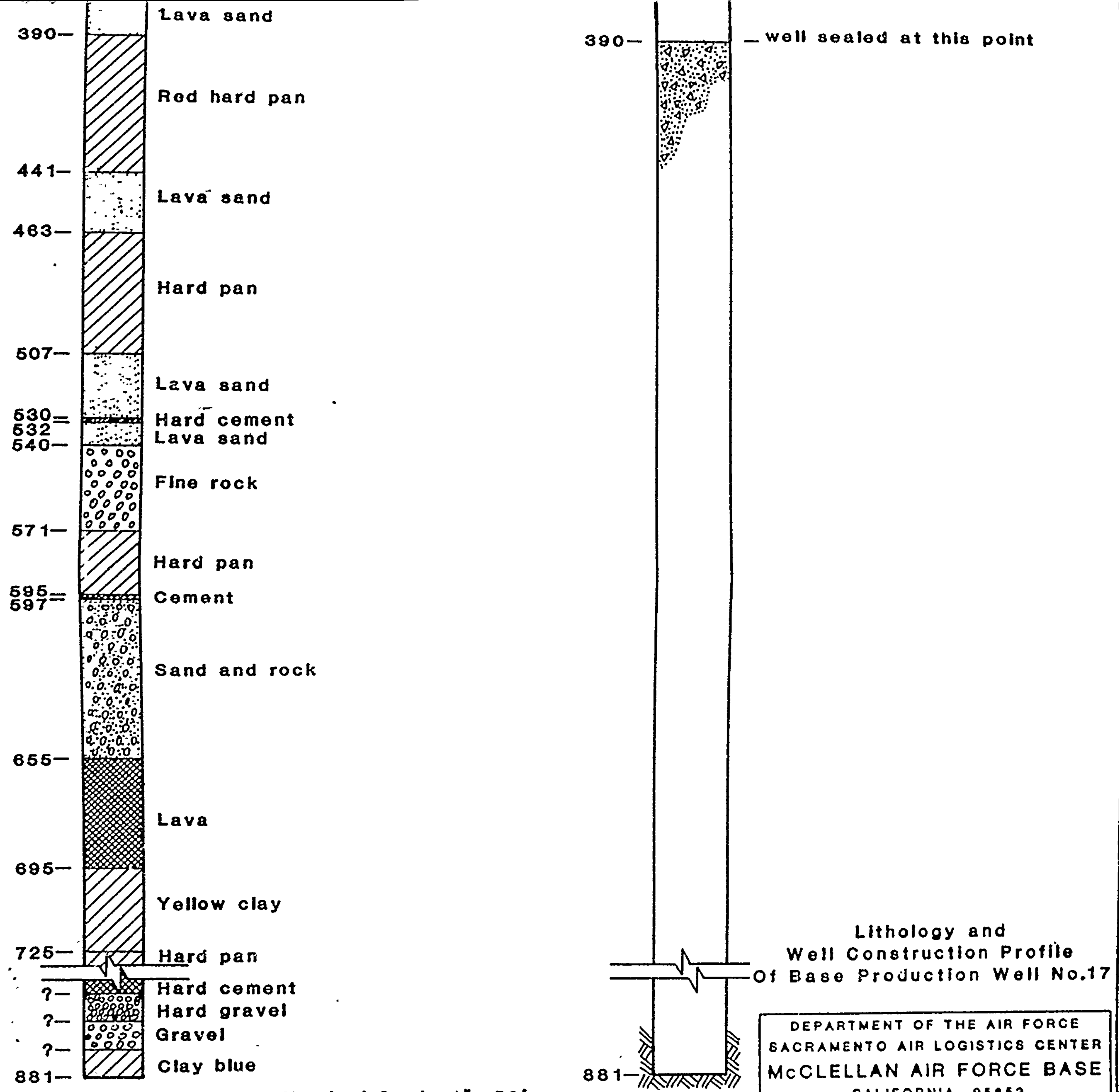
DEPARTMENT OF THE AIR FORCE
SACRAMENTO AIR LOGISTICS CENTER
McCLELLAN AIR FORCE BASE
CALIFORNIA 95652


K&E 5 YEARS BY MONTHS X 100 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
HISTORICAL WELL PROFILE
McClellan Air Force Base
Sacramento, California
WELL NO. BW-13
CAPACITY
SPECIFIC CAPACITY
STATIC WATER LEVEL
PUMPING WATER LEVEL
WATER LEVEL (feet)
SPECIFIC CAPACITY (gallons per minute per foot)
CAPACITY (gallons per minute)
0
20
40
60
80
100
120
140
160
180
200
2000
1500
1000
500
19 79
19 80
19 81
19 82
19 83
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
LUHDORFF AND SCALMANINI
Consulting Engineers


LITHOLOGY
2— Clay red
Hard pan
39— Sand
45— Clay
53— Hard pan
153— Sand, lava sand
171— Cemented hard
179— Hard pan
216— Sand and fine rock
230— Cement hard
262— Sand, lava sand
275— Hard shell
276— Hard pan
284— Fine gravel
290— Hard pan
300— Fine gravel
311— Hard pan red
376— Lava sand
390—
WELL PROFILE
16 inch diameter blank casing (typical)
16 inch diameter perforated pipe (typical)
216—
224—
286—
294—
302—
312—
353— ?
390— well sealed at this point



179—
Hard pan
216—
Sand and fine rock
230—
Cement hard
262—
Sand, lava sand
275
Hard shell
276
Hard pan
284
Fine gravel
290
Hard pan
300
Fine gravel
311
Hard pan red
376
Lava sand
390
Red hard pan
441
Lava sand
463
Hard pan
507
Lava sand
530
Hard cement
532
Lava sand
540
Fine rock
571
Hard pan
595
Cement
597
16 inch diameter blank casing (typical)
16 inch diameter perforated pipe (typical)
216
224
286
294
302
312
353
?
390
well sealed at this point



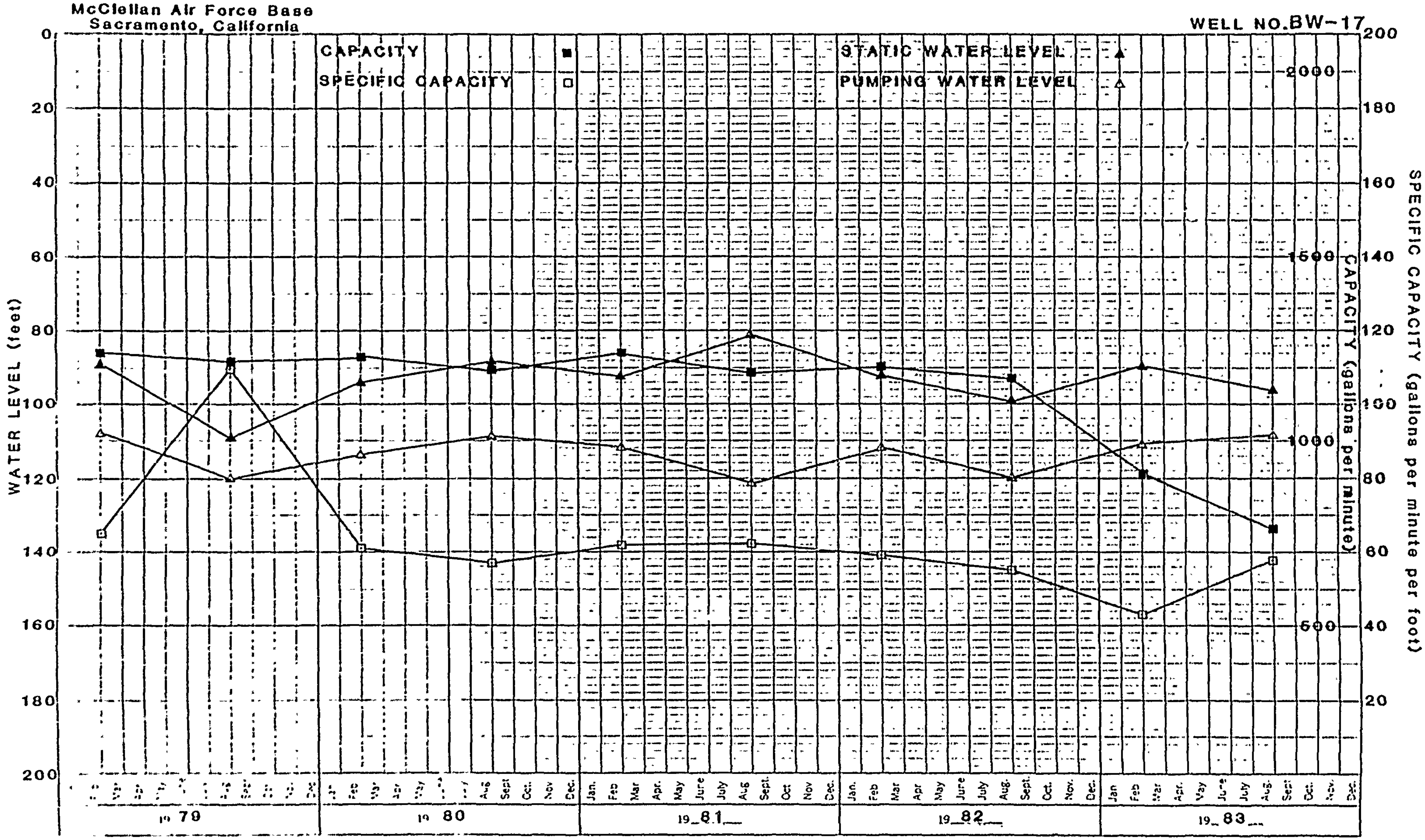
Vertical Scale 1" = 50'

Lithology and
Well Construction Profile
Of Base Production Well No.17

DEPARTMENT OF THE AIR FORCE
SACRAMENTO AIR LOGISTICS CENTER
McCLELLAN AIR FORCE BASE
CALIFORNIA 95652

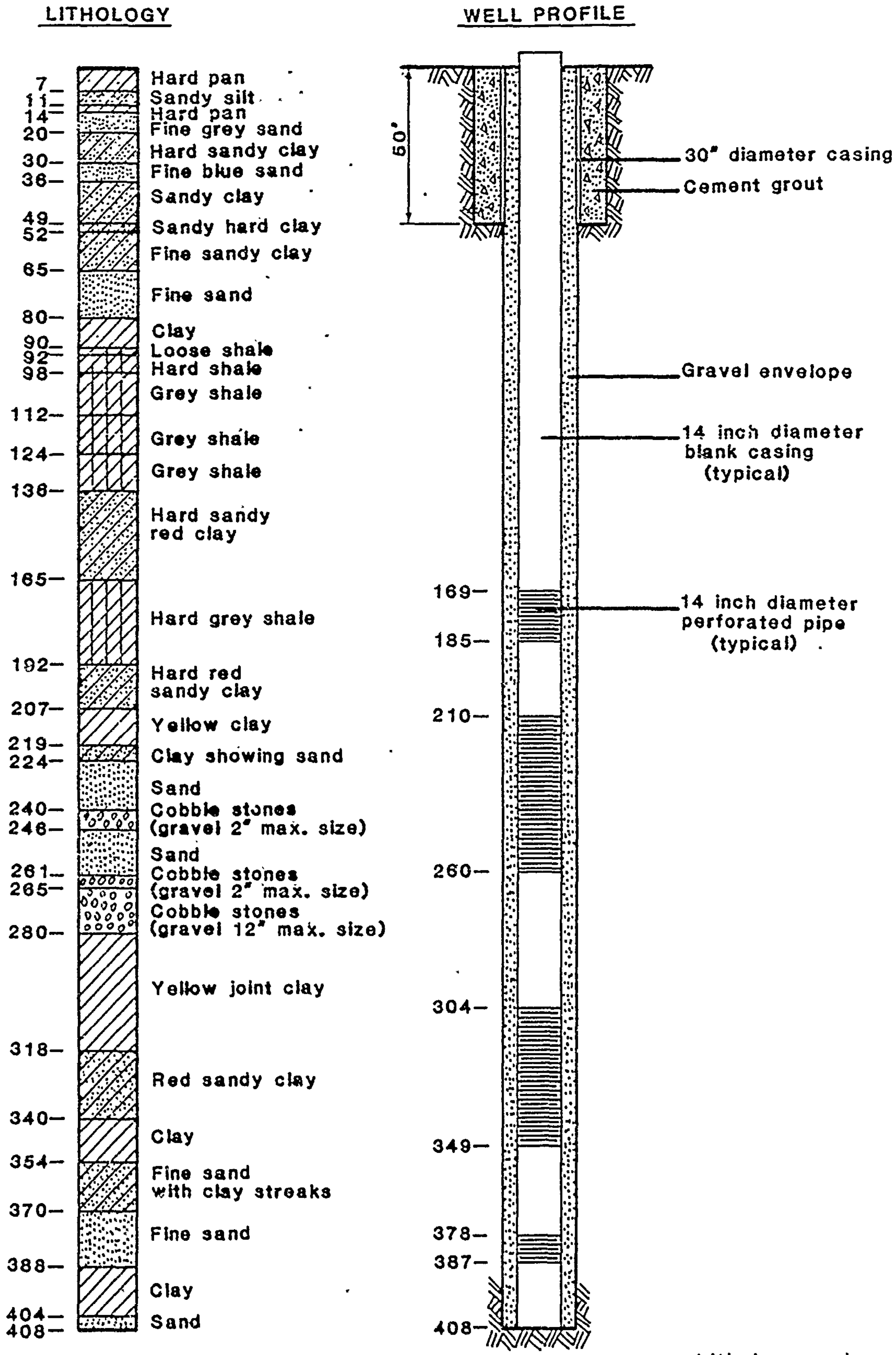
K+E 5 YEARS BY MONTHS X 100 DIVISIONS

HISTORICAL WELL PROFILE



LUHDORFF AND SCALMANINI
Consulting Engineers

Luhdorff & Scalmanini

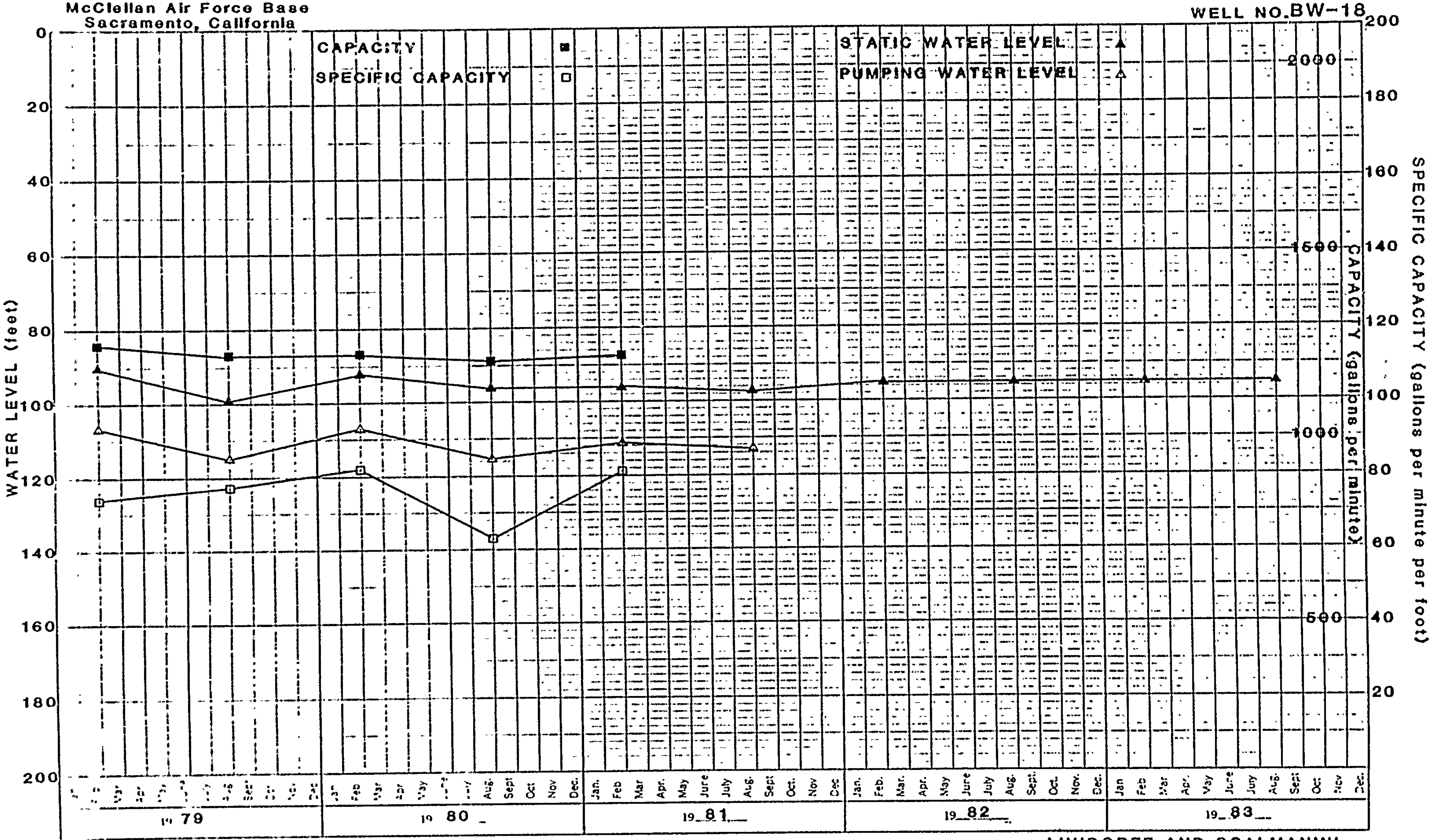


Lithology and
Well Construction Profile
Of Base Production Well No.18

Vertical Scale 1"= 50'

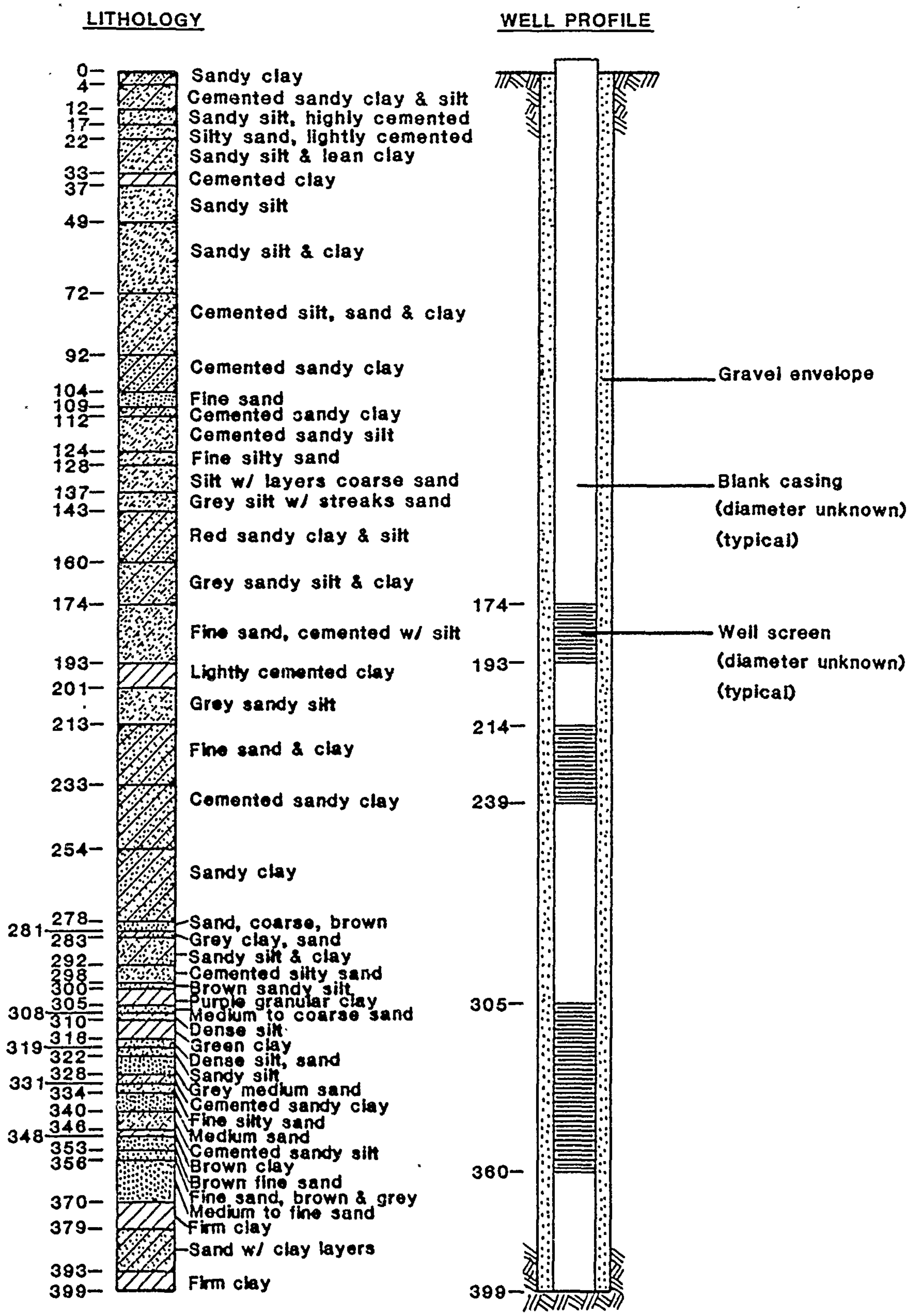
DEPARTMENT OF THE AIR FORCE
SACRAMENTO AIR LOGISTICS CENTER
McCLELLAN AIR FORCE BASE
CALIFORNIA 95652

HISTORICAL WELL PROFILE



LUHDORFF AND SCALMANINI
Consulting Engineers

Luhdorff & Scalmanini

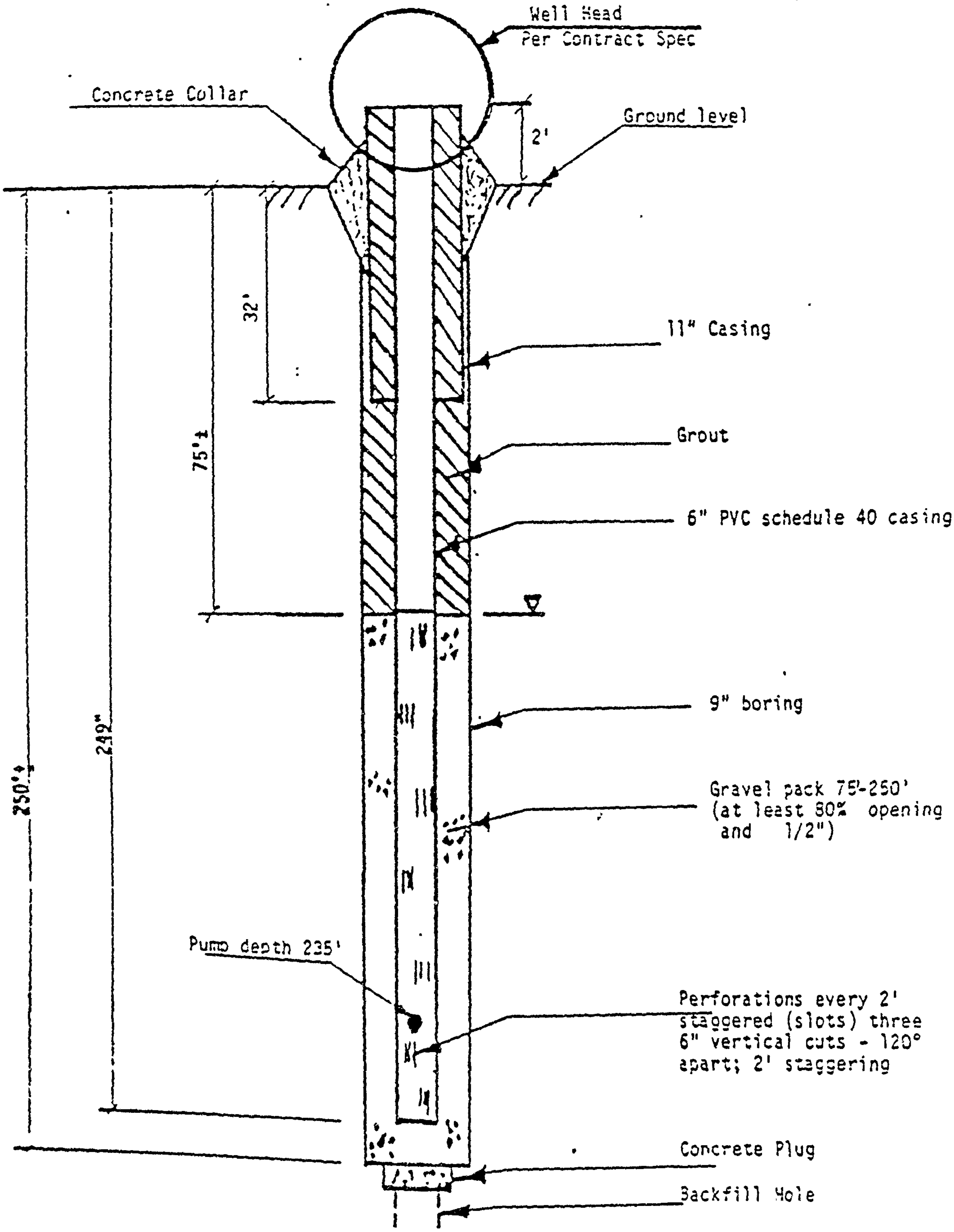


Vertical Scale 1" = 50'

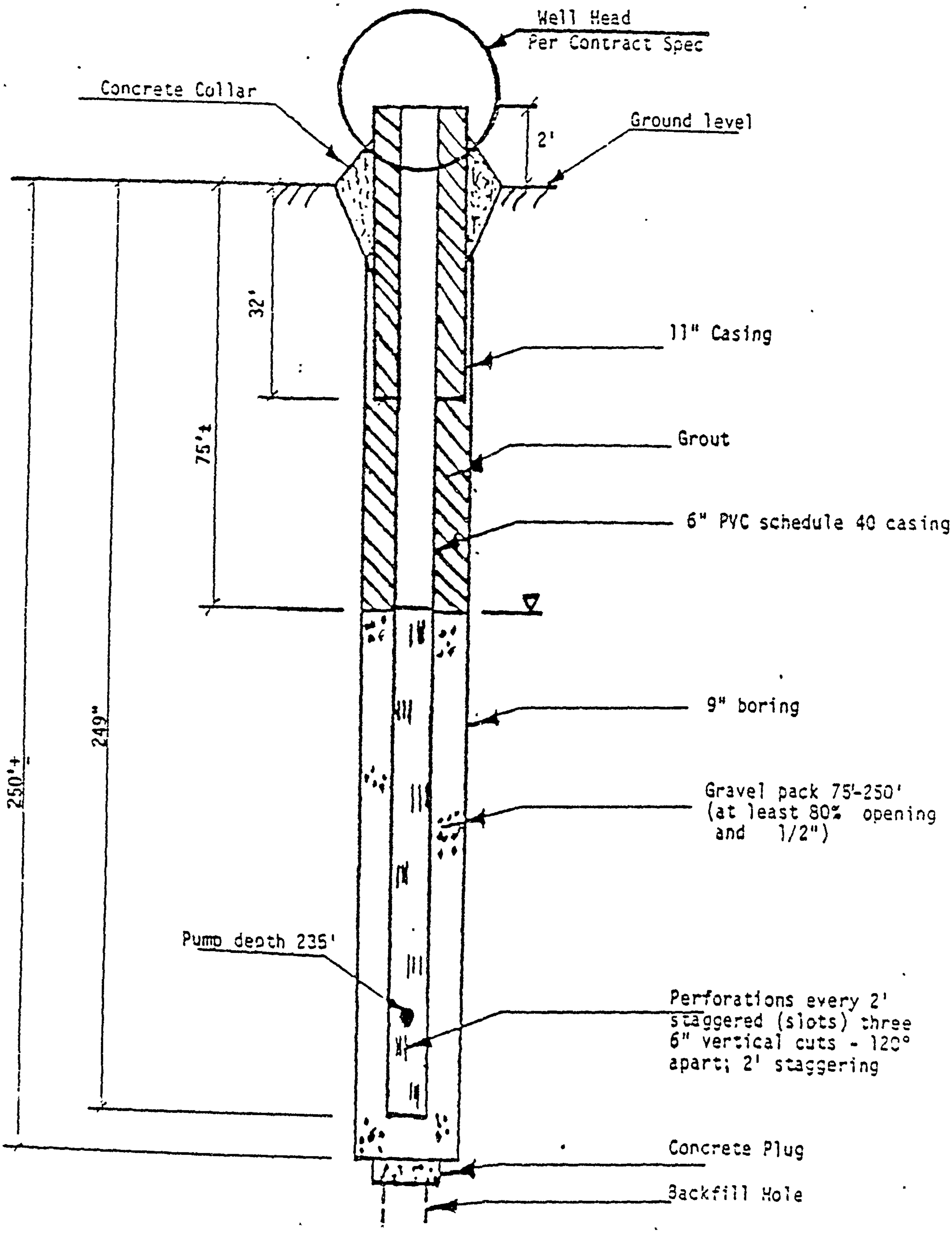
Lithology and
Well Construction Profile
Of Base Production Well No.19

DEPARTMENT OF THE AIR FORCE
SACRAMENTO AIR LOGISTICS CENTER
McCLELLAN AIR FORCE BASE
CALIFORNIA 95652

BASE MONITORING WELL MW 1



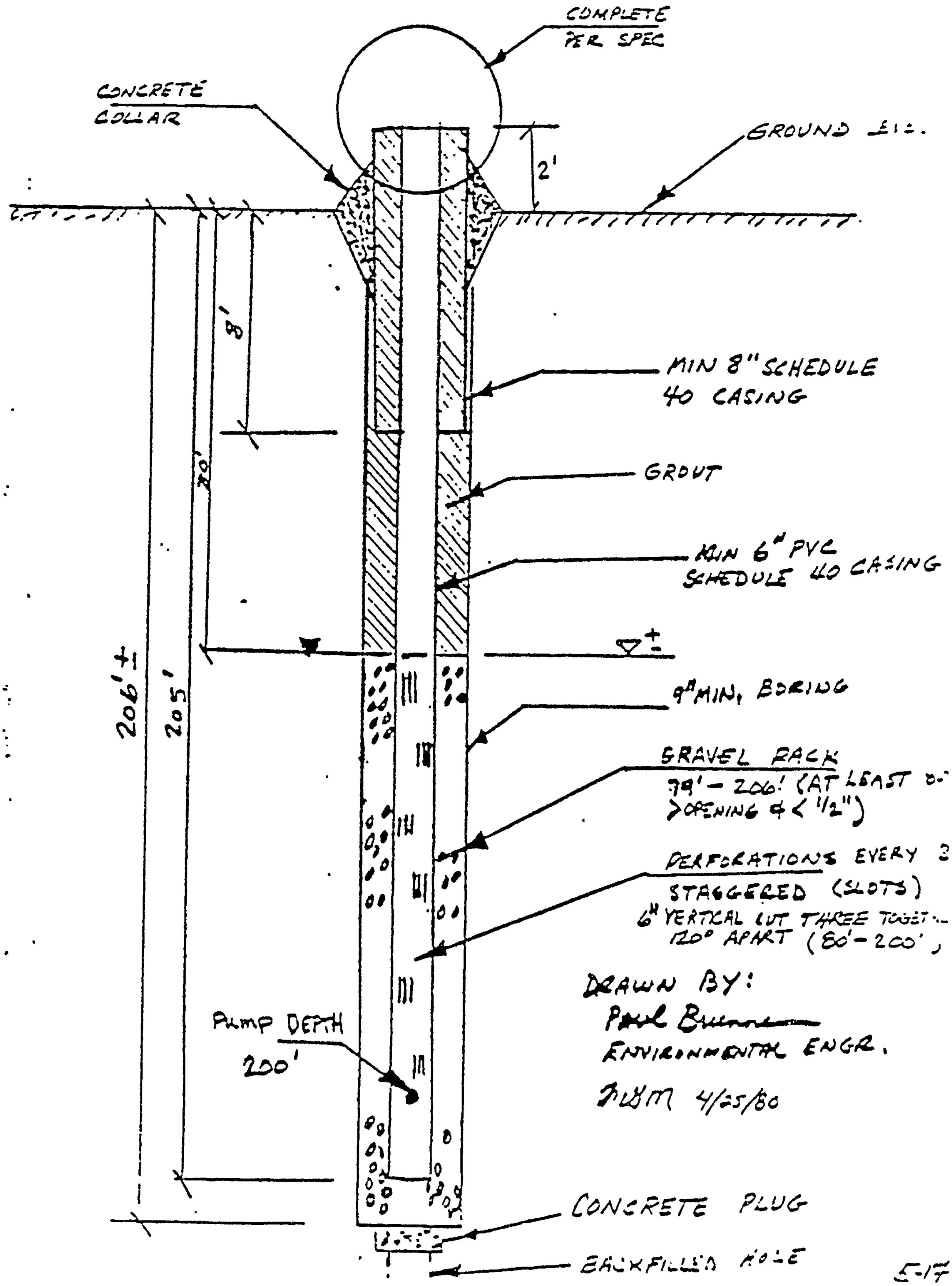
BASE MONITORING WELL MW 2



BASE MONITORING WELL MW3

WELL NO: 3
DATE: 25 APRIL 80
NO SCALE

LOCATION OF WELL PERFORATIONS
CONTRACT NO. F04699-80-C0205

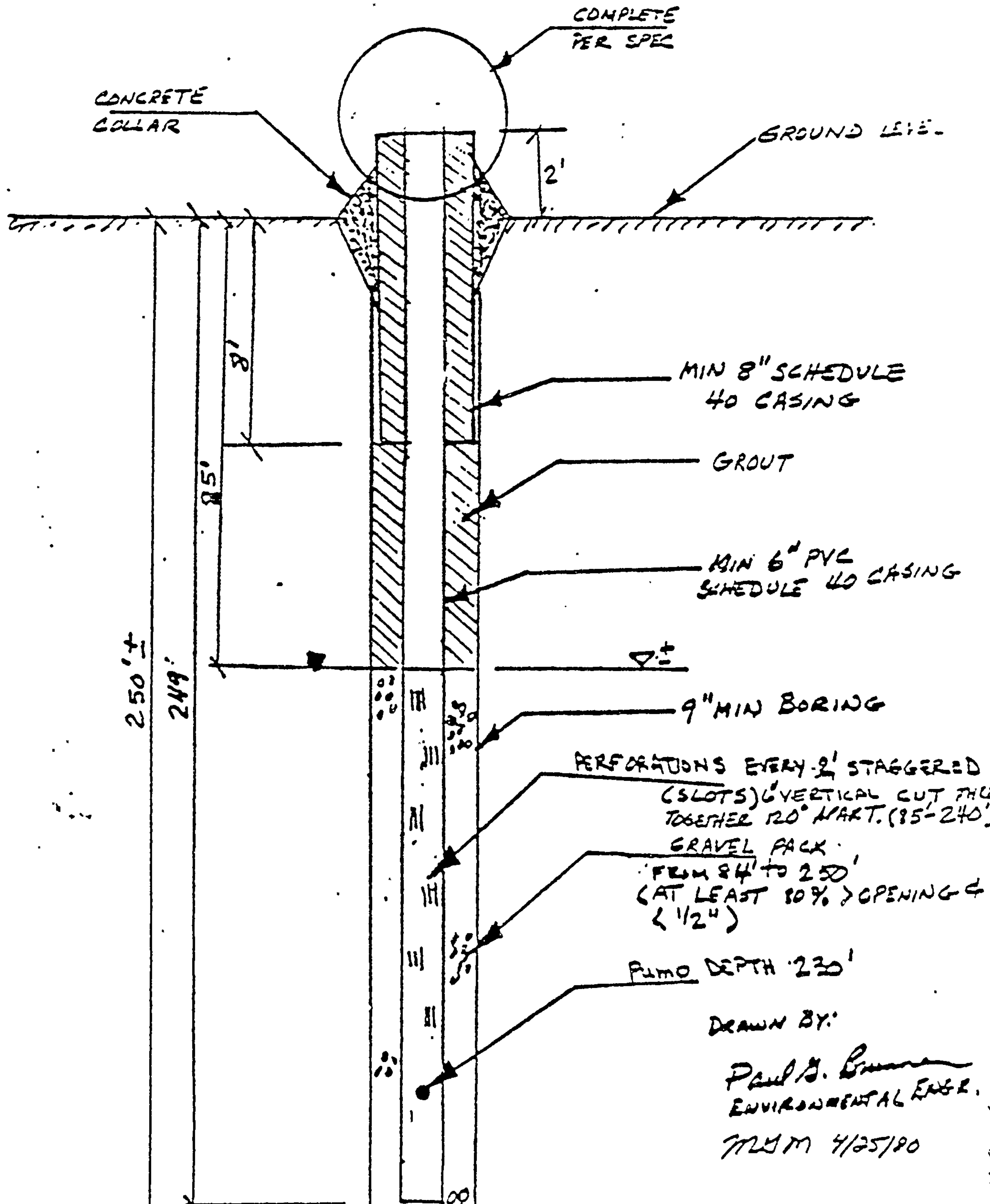


DRAWN BY:
ENVIRONMENTAL ENGR.
4/25/80

BASE MONITORING WELL MW4

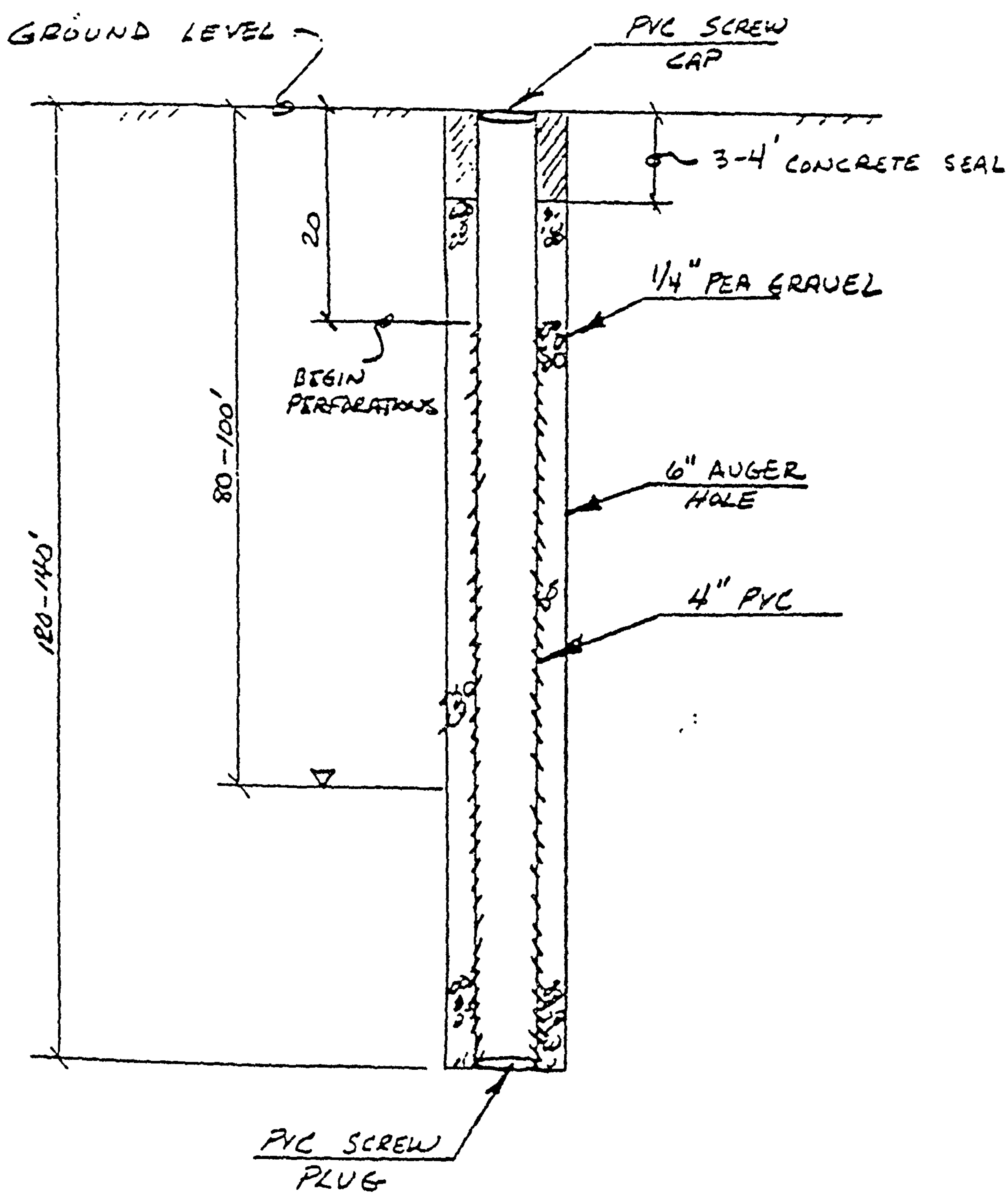
WELL No: 4
DATE: 25 APRIL 80
No SCALE

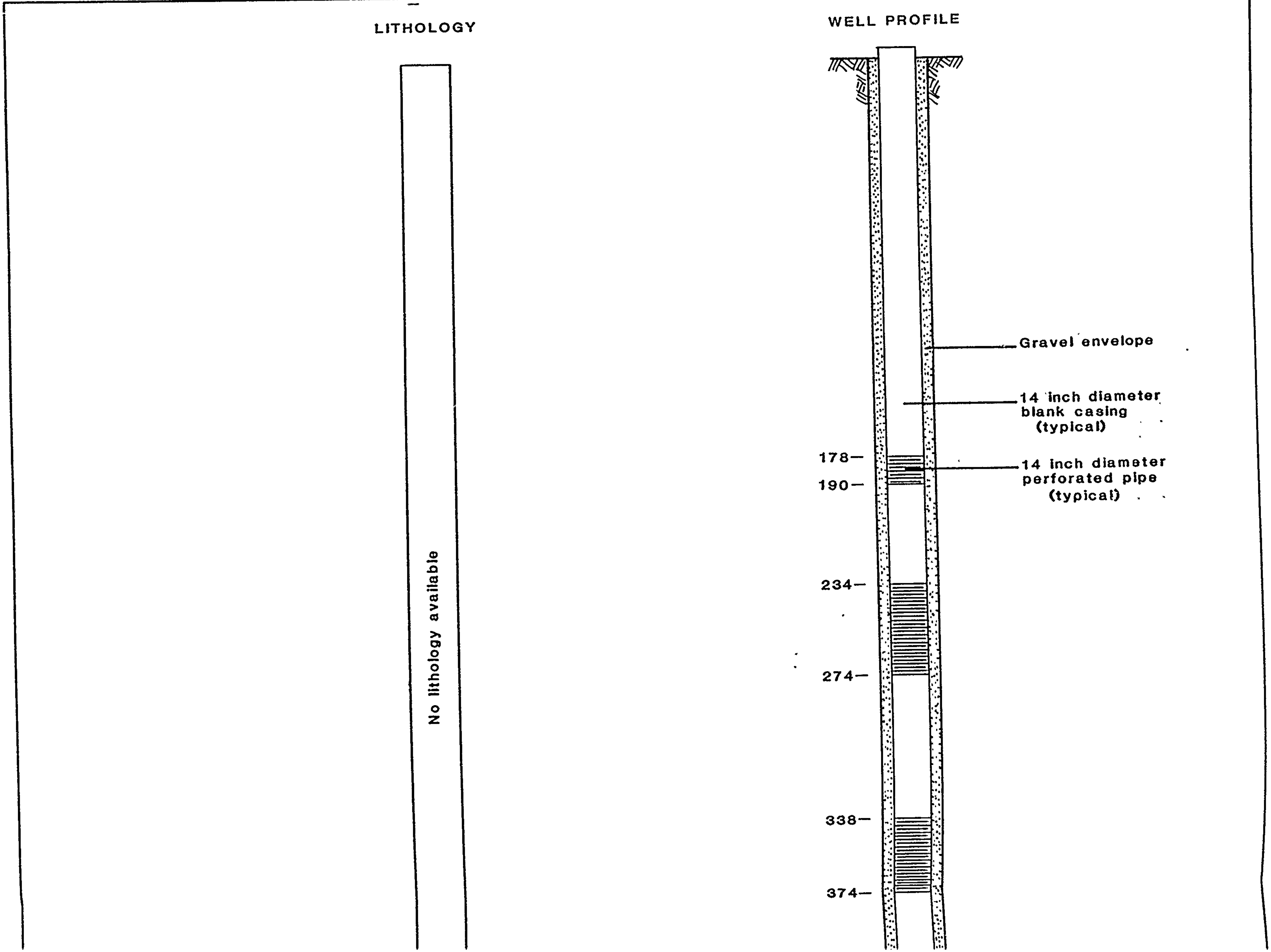
LOCATION OF WELL PERFORATIONS
CONTRACT No. F0 4699-80-C0285



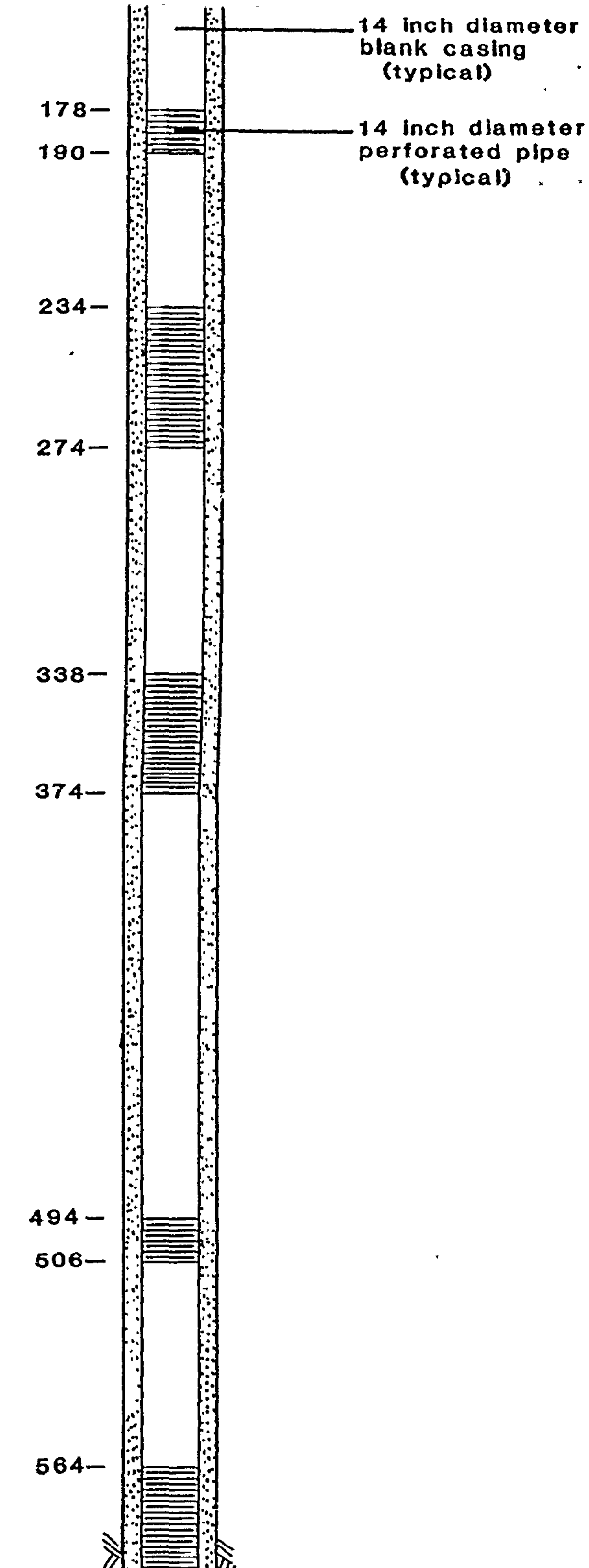
DRAWN BY:
Paul G. [signature]
ENVIRONMENTAL ENGR.
MGM 4/25/80

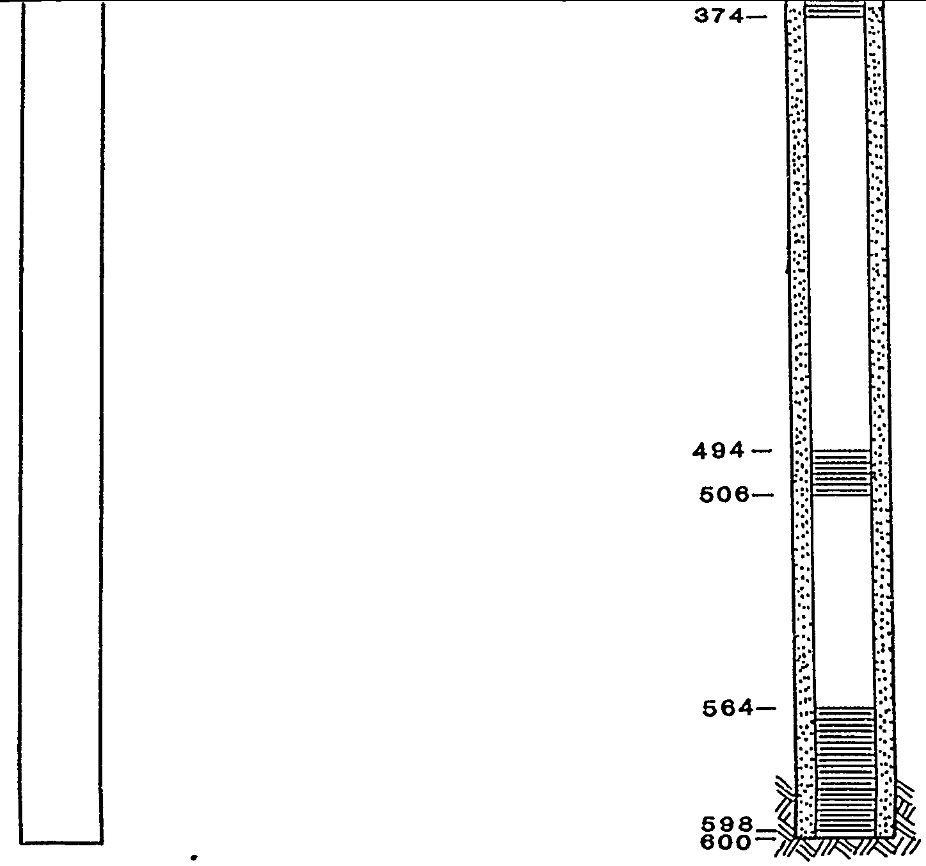
BASE MONITORING WELLS MW 5, 6, 7, 8, 9




LITHOLOGY
No lithology available
WELL PROFILE
Gravel envelope
14 inch diameter blank casing (typical)
14 inch diameter perforated pipe (typical)
178—
190—
234—
274—
338—
374—

No lithology available





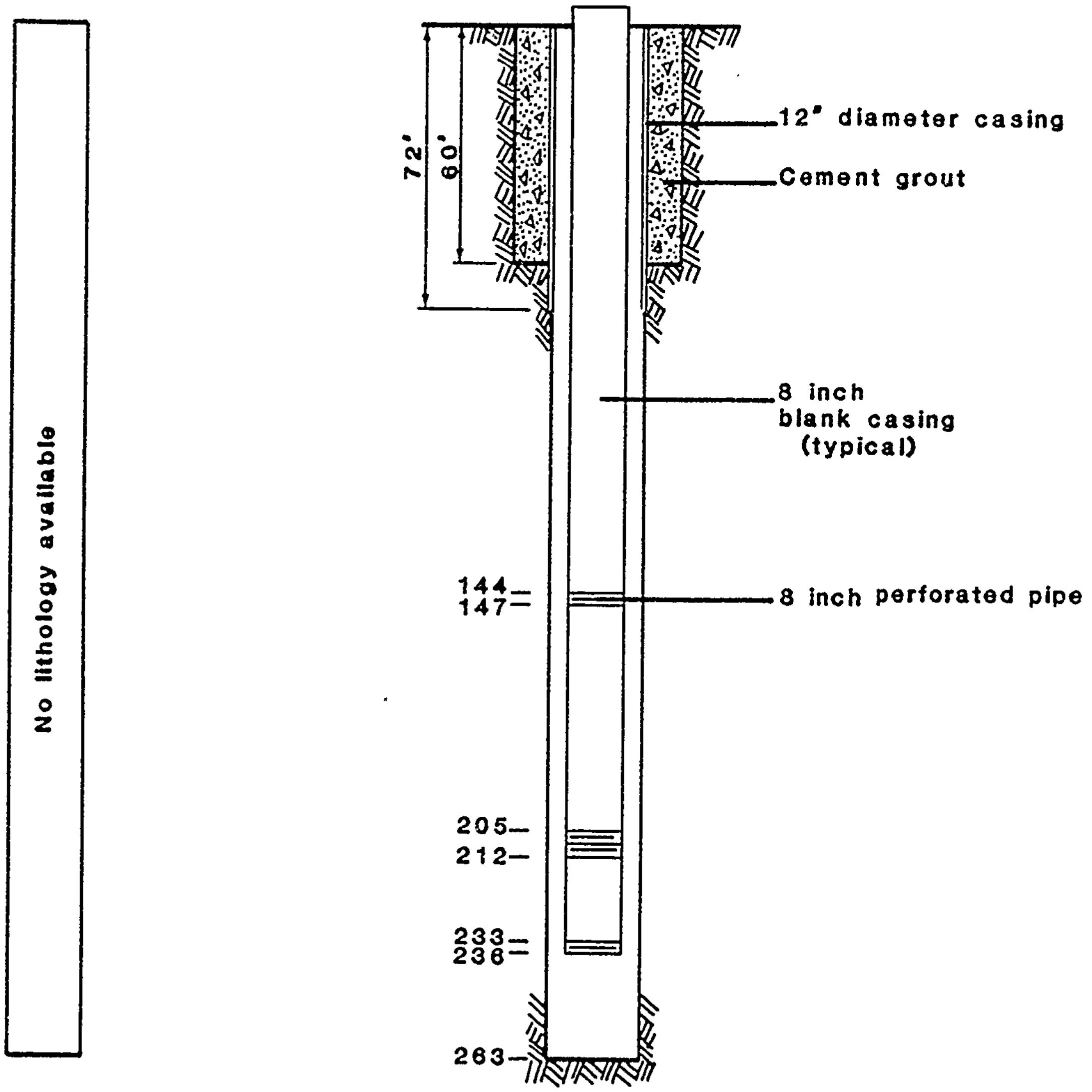
Vertical Scale 1" 50'

Lithology and
Well Construction Profile
Of Base Production Well No.20

DEPARTMENT OF THE AIR FORCE
SACRAMENTO AIR LOGISTICS CENTER
McCLELLAN AIR FORCE BASE
CALIFORNIA 95652

LITHOLOGY

WELL PROFILE

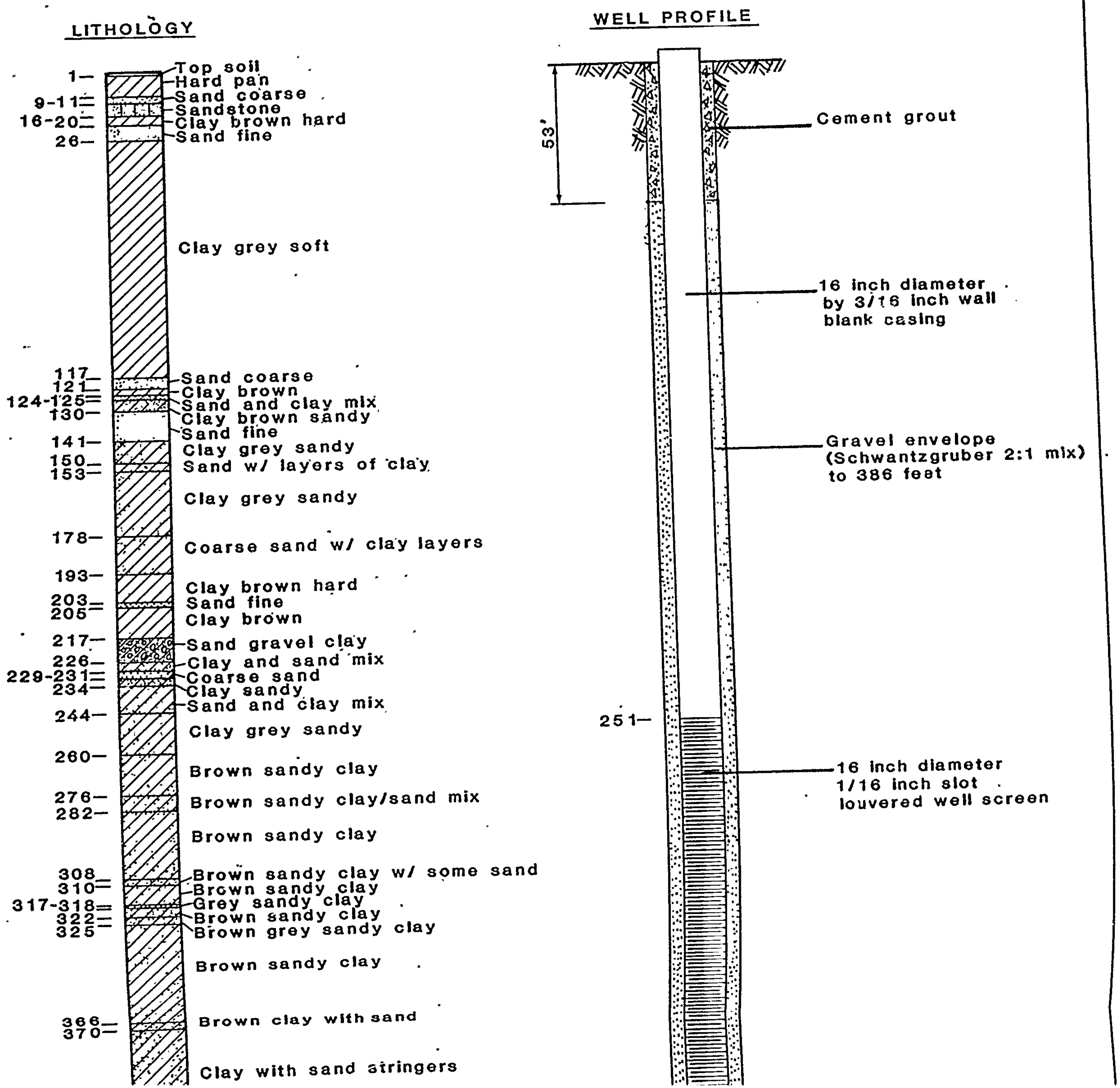


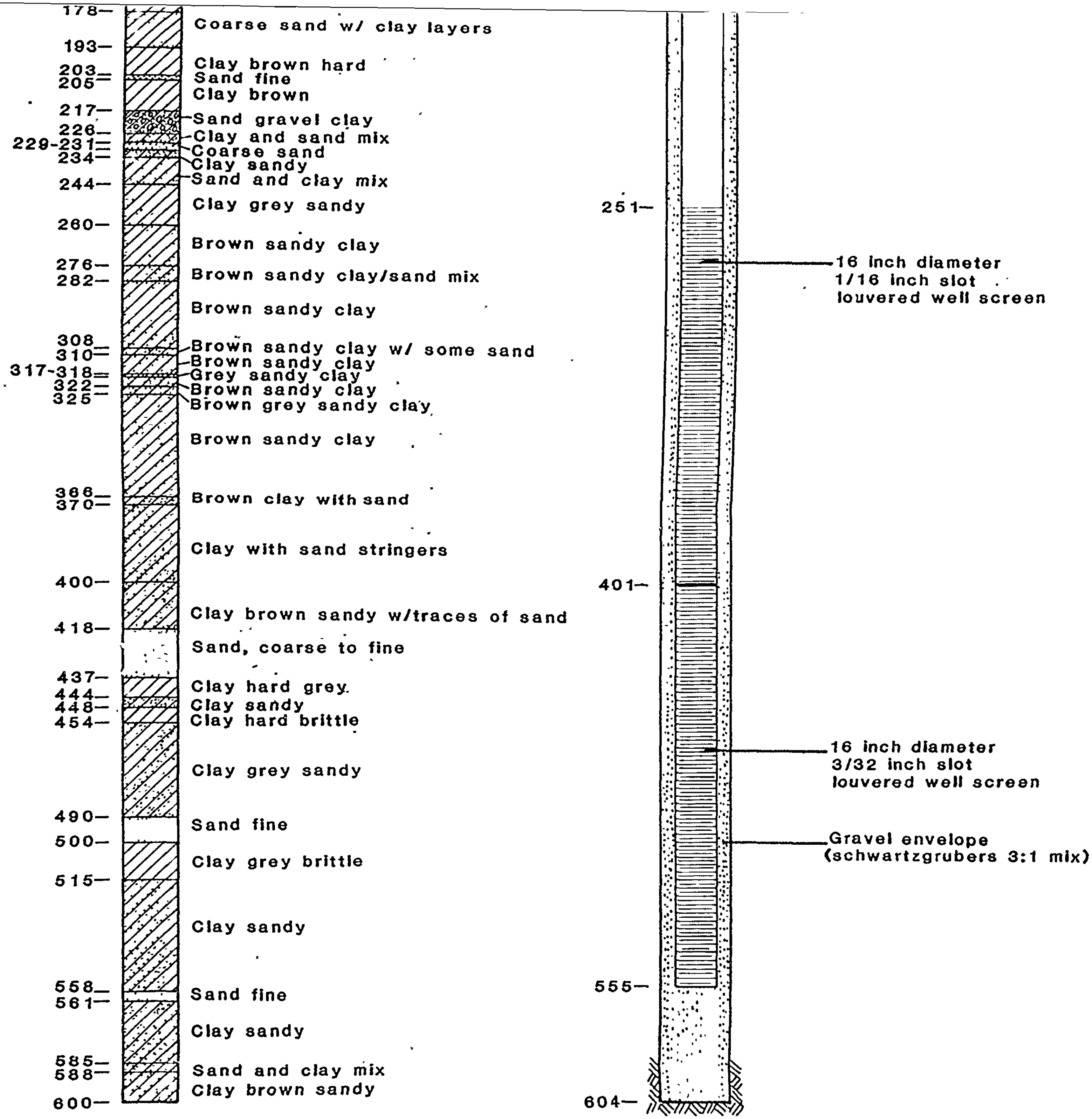
Vertical Scale 1"= 50'

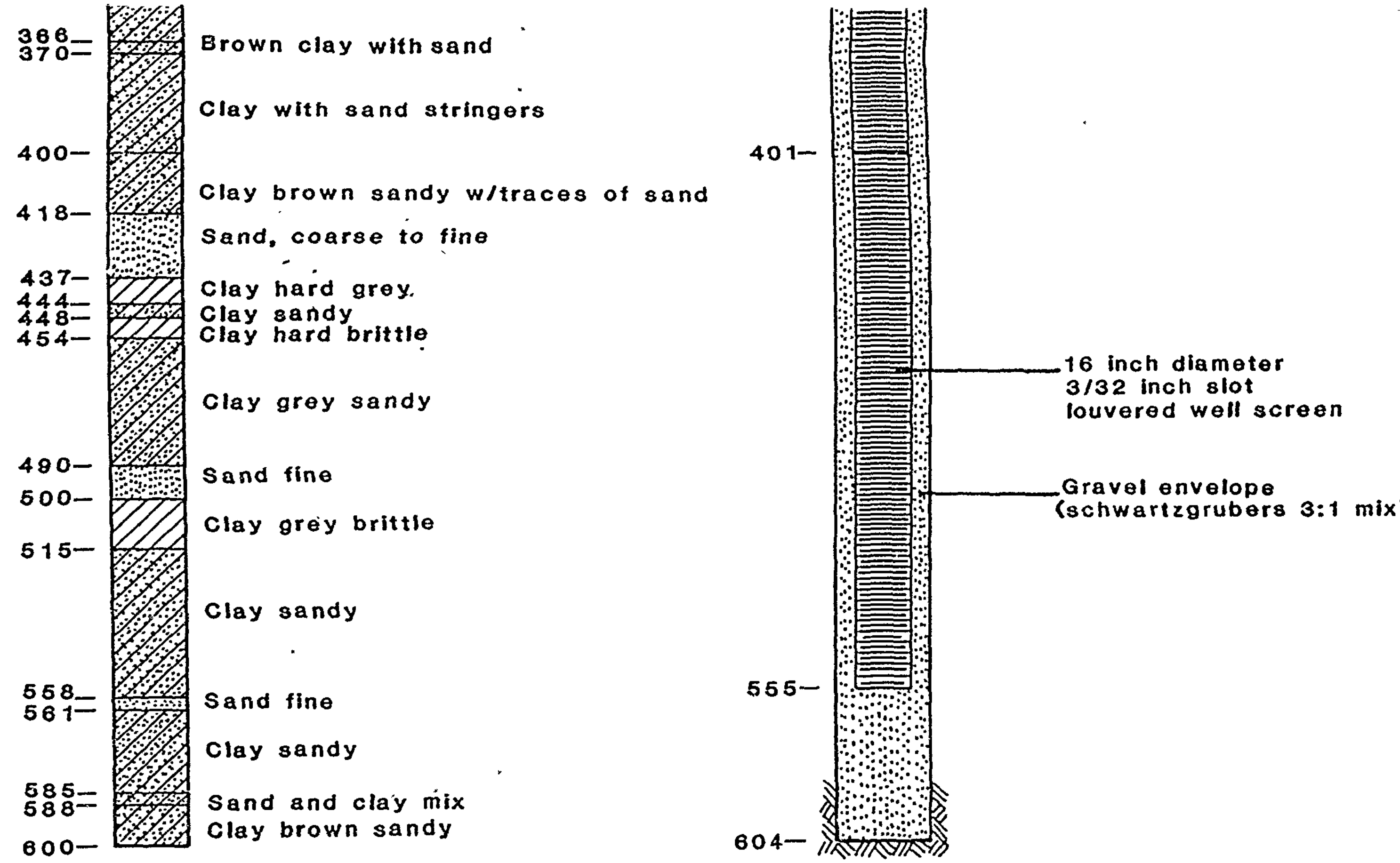
Lithology and
Well Construction Profile
Of Base Production Well No.28

DEPARTMENT OF THE AIR FORCE
SACRAMENTO AIR LOGISTICS CENTER
McCLELLAN AIR FORCE BASE
CALIFORNIA 95652

Luhdorff & Scalmanini




178
Coarse sand w/ clay layers
193
Clay brown hard
203
Sand fine
205
Clay brown
217
Sand gravel clay
226
Clay and sand mix
229-231
Coarse sand
Clay sandy
234
Sand and clay mix
244
Clay grey sandy
260
Brown sandy clay
276
Brown sandy clay/sand mix
282
Brown sandy clay
308
Brown sandy clay w/ some sand
310
Brown sandy clay
317-318
Grey sandy clay
322
Brown sandy clay
325
Brown grey sandy clay
Brown sandy clay
366
Brown clay with sand
370
Clay with sand stringers
400
Clay brown sandy w/traces of sand
418
Sand, coarse to fine
437
Clay hard grey
444
Clay sandy
448
Clay hard brittle
454
Clay grey sandy
490
Sand fine
500
Clay grey brittle
515
Clay sandy
558
Sand fine
561
Clay sandy
585
Sand and clay mix
588
Clay brown sandy
600
251
16 inch diameter
1/16 inch slot
louvered well screen
401
16 inch diameter
3/32 inch slot
louvered well screen
Gravel envelope
(schwartzgrubers 3:1 mix)
555
604



Vertical Scale 1" = 50'

Lithology and
Well Construction Profile
Of Base Production Well No.29

DEPARTMENT OF THE AIR FORCE
SACRAMENTO AIR LOGISTICS CENTER
McCLELLAN AIR FORCE BASE
CALIFORNIA 95652

APPENDIX E

APPLICABLE EQUIPMENT EMPLOYED IN WELL SEALING OPERATIONS

HALLIBURTON DIVISION LABORATORY

SANTA FE SPRINGS, CALIFORNIA – ANCHORAGE, ALASKA – LOS ANGELES DIVISION

MAINTAINED BY HALLIBURTON COMPANY

No. CO-145.1000-112?

LABORATORY REPORT

To Mr. J. I. Evanoff

Halliburton Services

Rio Vista, CA

Date November 28, 1983

We give below results of our examination of several squeeze cement slurries

Submitted by

Marked McClellan Air Force Base Water Wells 150ft BHSQ 75^{O}FBHTS

PURPOSE

The purpose of these tests is to design a cement slurry for a braden head squeeze of about a dozen water disposal wells. The cement slurry must be still pumpable after setting static for 45 minutes and have fair fluid loss properties. Tests were also conducted for initial set times and compressive strengths.

HALLIBURTON DIVISION LABORATORY

SANTA FE SPRINGS, CALIFORNIA . LOS ANGELES DIVISION

MAINTAINED BY HALLIBURTON SERVICES

DATA

Slurry Composition:	Permenante Class G Cement (11/2)	
Water Ratio:	.67 cuft/sx	
Slurry Volume:	1.15 cuft/sx	
Slurry Density:	118 pcf or 15.8#/gal.	
Extra Additive	.25% Halad-4	.25% Halad-9
$75^{\circ}F$ Fluid Loss:	200cc/30 minutes	300 cc/30 minutes
$75^{\circ}F$ Free Water:	0.1%	0.6%
$75^{\circ}F$ Rheology:		
600 RPM	300+	147
300 "	250	97
200 "	175	78
100 "	100	58
$75^{\circ}F$ Compressive Strength:	(@ Atmospheric conditions in water bath)	
Initial Set:	3 hours	5½ hours
8 hours:	285 psi	125 psi
$75^{\circ}F$ Pumpability:	Passes Test*	Passes Test*

The cement slurries were mixed for 15 minutes at $75^{\circ}F$ and 500 psi in a HP-HT Consistometer. Then the slurries were allowed to set static for 45 minutes under the same temperature and pressure before turning on the consistometer again. After the consistometer resumed mixing of the cement slurries any change in viscosity or pumpability of the slurries was noted. The slurries were allowed to mix an additional hour, before terminating the test.

*Note: The Halad-4 slurry saw a large gel strength buildup in viscosity after setting static 45 minutes, but the viscosity almost immediately broke back down to the original viscosity of the slurry. The Halad-9 slurry saw almost no viscosity buildup after setting static for 45 minutes. Both slurries were still pumpable after mixing for an additional hour.

cc: Mr. J. Diller Mr. W. Ostroot

Respectfully submitted,

Laboratory Analyst

M. Daugherty

HALLIBURTON SERVICES

By Tom Kealy

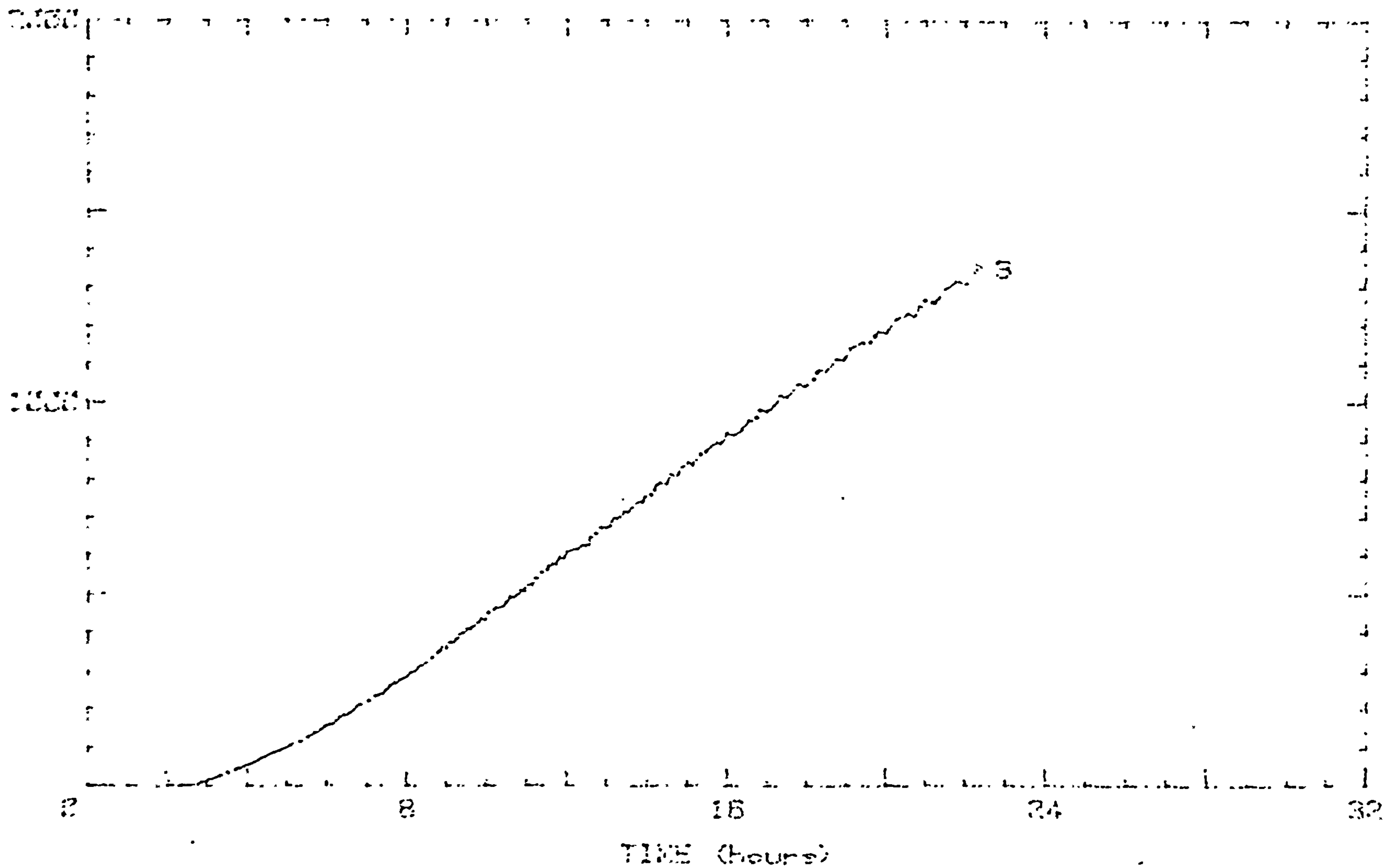
Cement test accuracy data indicate that an average range of confidence for cement testing is ± 20% depending on specific well conditions.

CEMENT NO.: Air Force
DATE:
PRESSURE: 500 psi
TEMPERATURE: 75°F

CEMENT: G + .25% Halad-4

ULTRASONIC
CEMENT ANALYZER
HALLIBURTON SERVICES

INITIAL SET: 50 @ 7:55
STRENGTH 1 : 500 @ 10:47
STRENGTH 2 : 1000[illegible]
CURR. STR. : 1381 @ 20:37



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HALLIBURTON DIVISION LABORATORY

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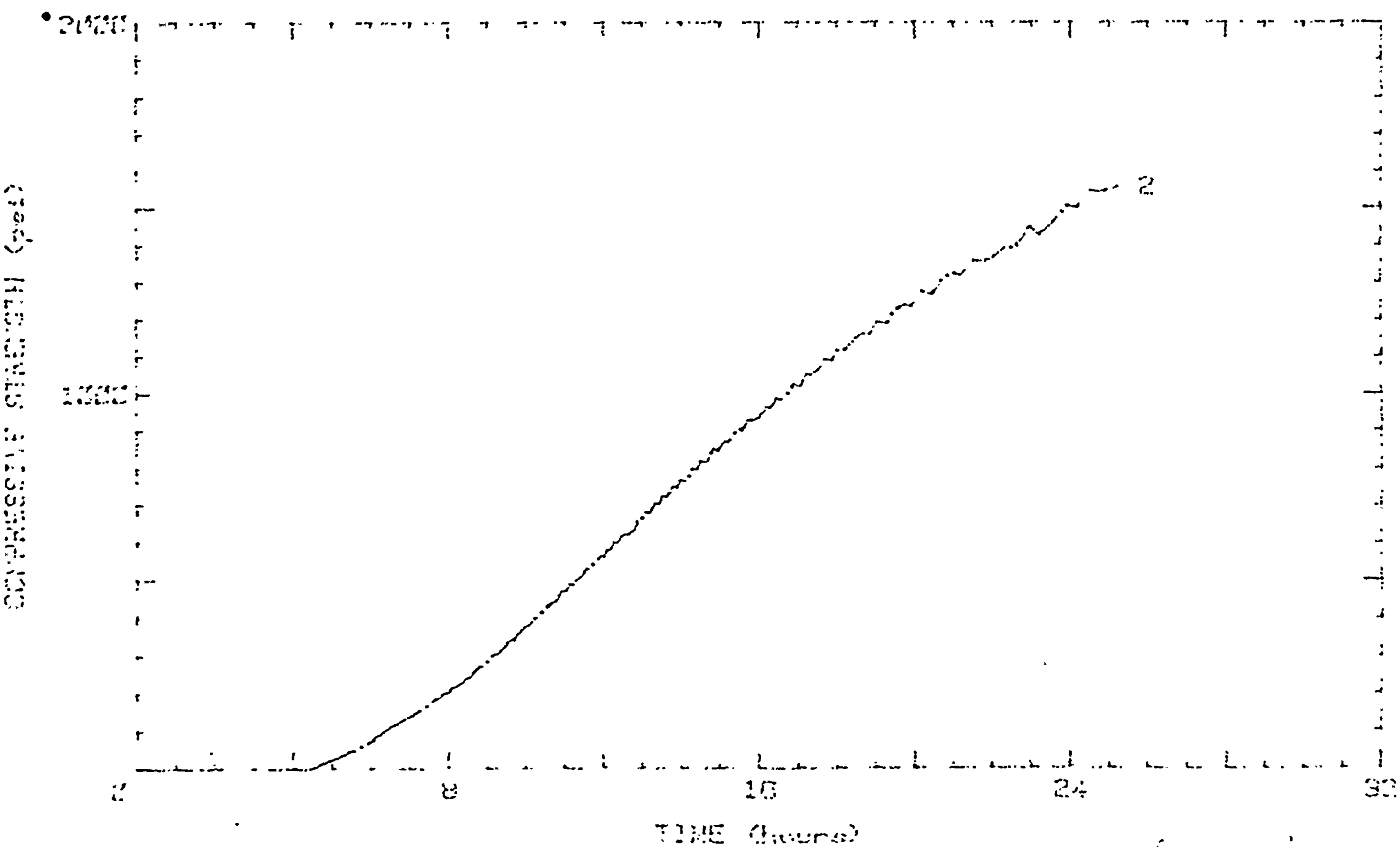
MAINTAINED BY HALLIBURTON SERVICES

PROJECT NO.: Air Force
DATE:
PRESSURE: 500psi
TEMPERATURE: 75°F

CEMENT: G+.25% Halad-9

ULTRASONIC
CEMENT ANALYZER
HALLIBURTON SERVICES

INITIAL SET: 50 @ 5:38
STRENGTH 1 : 500 @ 11:31
STRENGTH 2 : 19999
CURR. STR. : 1559 @ 25:28



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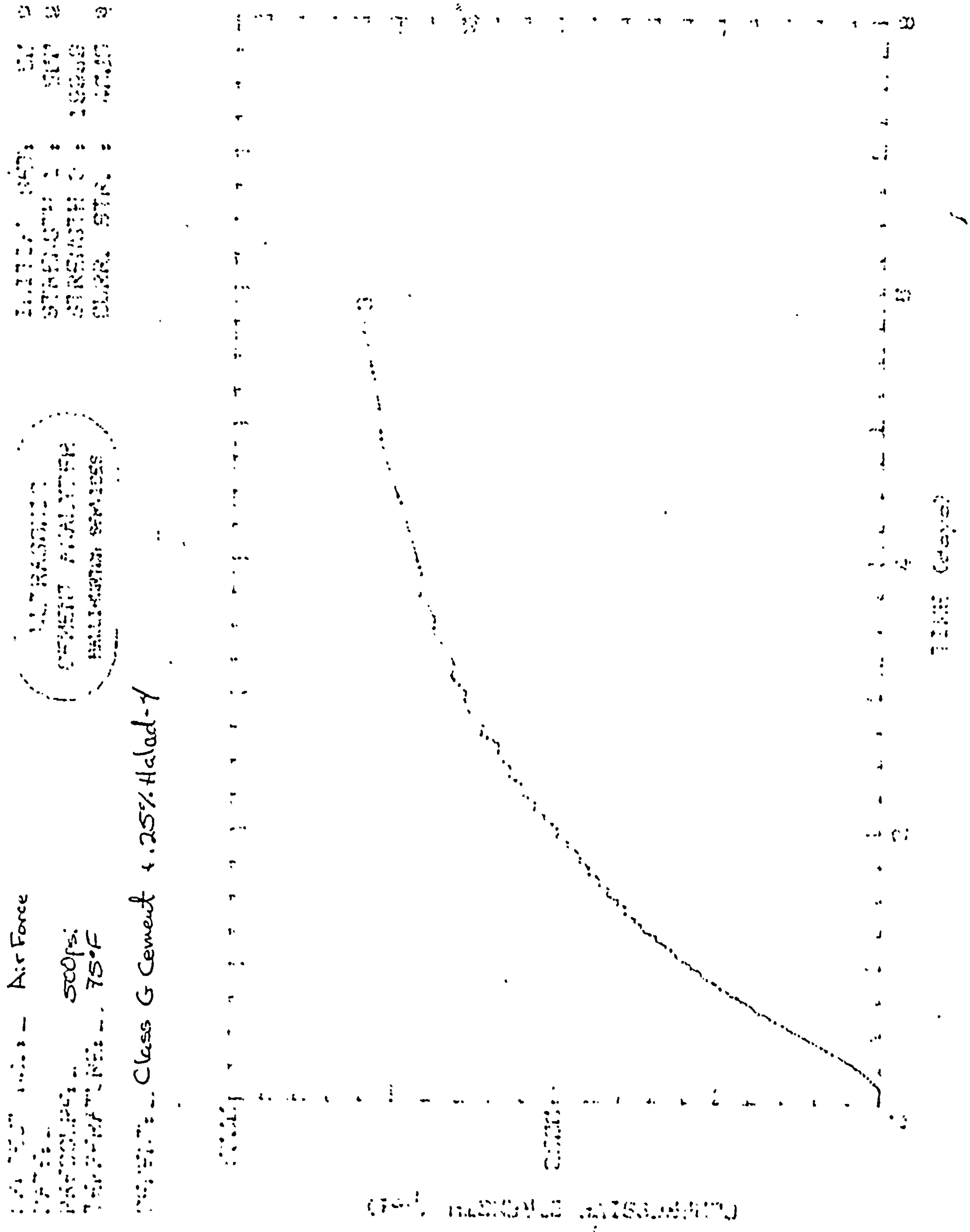
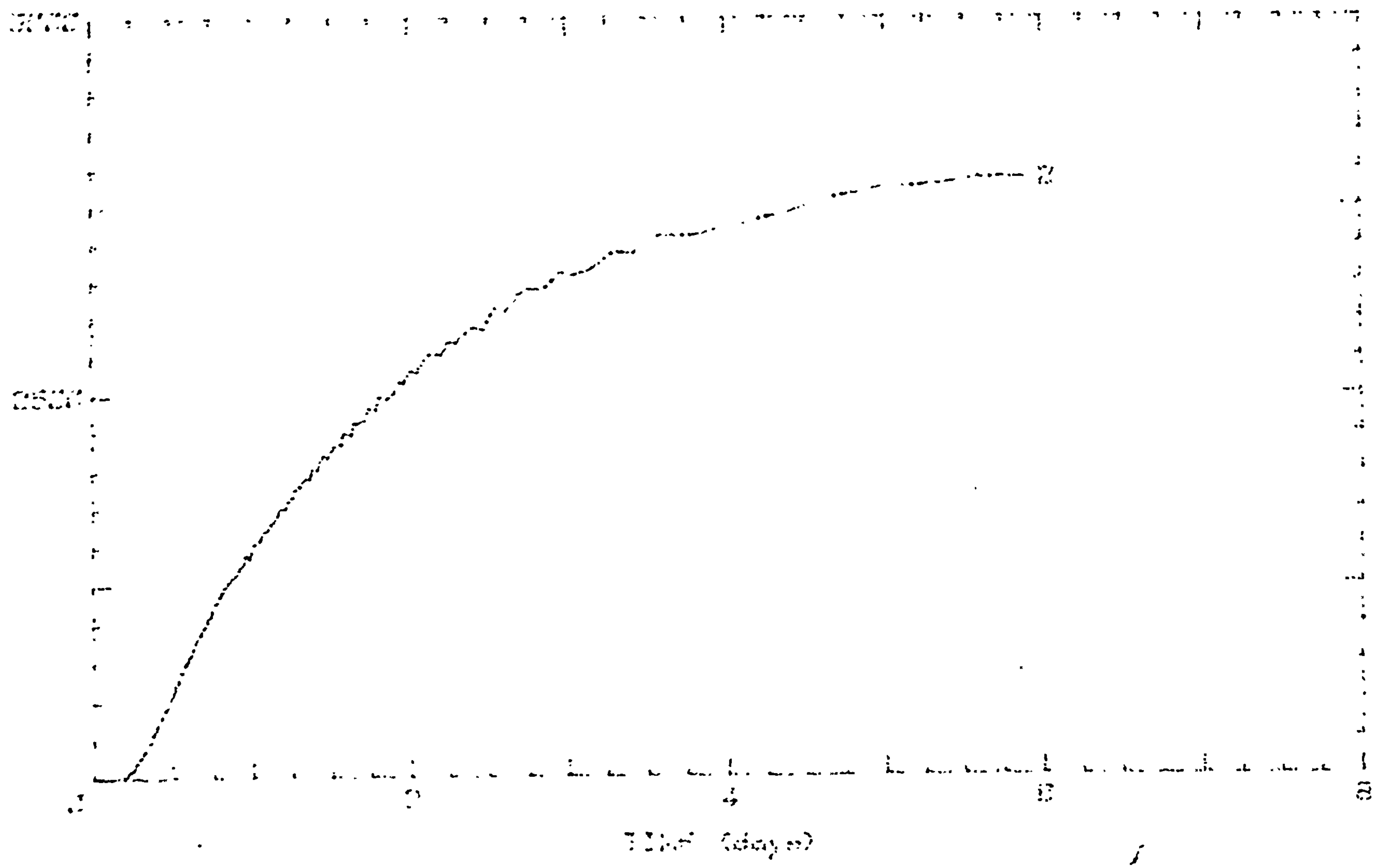


Air Force

500 psi

75°F

Class G Cement + .25% Halad-9



HALLIBURTON DIVISION LABORATORY

SANTA FE SPRINGS, CALIFORNIA - LOS ANGELES DIVISION

MAINTAINED BY HALLIBURTON SERVICES

Operating Features

The main feature of the RCM system is the recirculating mixer used in conjunction with a two-compartment, 8-bbl mixing tub equipped with a turbine agitator in each compartment. The mixer combines fresh water and recirculated slurry with dry cement. These components are partially mixed and then discharged into the first compartment of the tub.

The rate at which dry cement enters the mixer is controlled by a cement wheel located on the throttling valve on top of the mixer. The fresh water rate is controlled by the mixing manifold atop the 8-bbl tub.

In the first compartment of the tub, the slurry is blended by an agitator, recirculated by a centrifugal pump, and weighed by a densometer. Any weight variations are corrected automatically. When the first compartment is full, the slurry flows over a weir to the second compartment. Flowing over the weir helps remove entrained air.

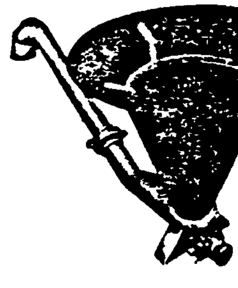
The second compartment already contains some slurry at the desired weight. The combined slurries are blended further by the agitator in the second compartment in order to help insure a uniform mixture. This slurry is then pumped downhole.

Retention time in the 8-bbl tub gives the slurry time to achieve effects from time-dependent additives. Slurries can be mixed at pump rates from 0 to 12 bbl min with the RCM system. Weights over 22 lb/gal have been successfully mixed. Whatever the [illegible] or pumping rate, the RCM [illegible] help insure a uniform slurry [illegible]

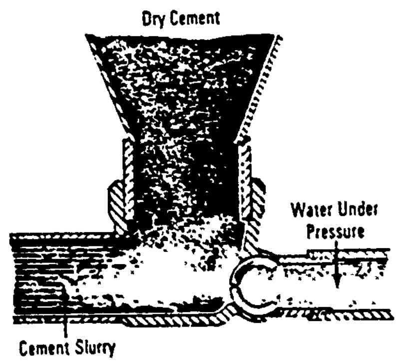
Standard Features

- RCM mixer
- 8-bbl two-compartment tub
- Recirculating water centrifugal pump
- Fresh water centrifugal pump
- Densometer (u-tube or radioactive)
- Mixing manifold
- Two hydraulic agitators
- Cement throttling valve

Jet-Type Mixer



SCHEMATIC OF JET MIXER



The Halliburton standard high pressure hydraulic jet-type mixer system revolutionized oil well cementing. The heart of the system is a rugged compact unit, weighing around two hundred pounds. It consists of a funnel shaped hopper, a mixer bowl, discharge line, sump tub and water supply lines. The unit functions by forcing a stream of water through a jet, across the bowl into a discharge line, then into a sump tub from which the cement slurry is taken away by the cementing pumps.

The stream of water passing through the bowl creates a vacuum which pulls the dry cement into the bowl from the hopper immediately above. As the cement enters the jet stream of water, it is thoroughly mixed in the turbulent flow that occurs in the appropriately designed discharge pipe. Mixers of this type, when supplied with sufficient water under mixing pressure and adequate feed rate of cement, are capable of producing normal slurry at a rate of 50 cu ft per minute. The high-pressure jet type mixer, developed more than 45 years ago, has not been equaled in providing the excellent fluid shearing action for very effective mixing of cement and water. It is very simple, reliable and has been time proven on millions of cementing operations.

For jet-type mixers, Halliburton has developed several efficient modifications in the low energy or high volume systems. With the low energy system, the high pressure displacement pumps are available to handle the mixed slurry. A low pressure low energy type auxiliary water pump is utilized to supply the mixing water. This, in effect, permits a dual pump type cementing unit having the low energy mixing system do the work of two cementing units which are not so equipped. The Rotary Jet Mixer is normally employed with the low energy system. This mixer operates on the same basic principle as the jet-type mixer, but has several sizes and configurations of jets in a rotatable turret. These jets are selectable and can be used to compensate for changes in mixing rates or changes in the cementing compositions without interrupting the mixing operations at rates as high as 60-65 cu ft per minute and as low as 3-4 cu ft per minute; the slurry in these cases has been of necessary high quality for the purpose intended.

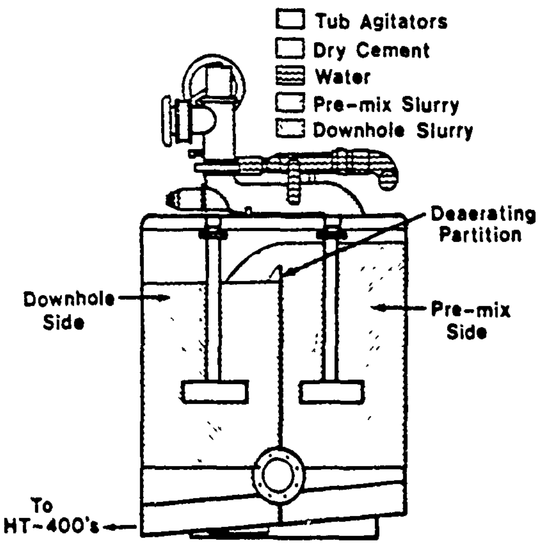
Halliburton Mixers

The purpose of a mixing system on any cementing operation is to proportion thoroughly and continuously blend the dry cementing compositions with the carrier fluid. When this is properly accomplished, the end result is a cementing slurry with predictable properties which is supplied at the desired rate.

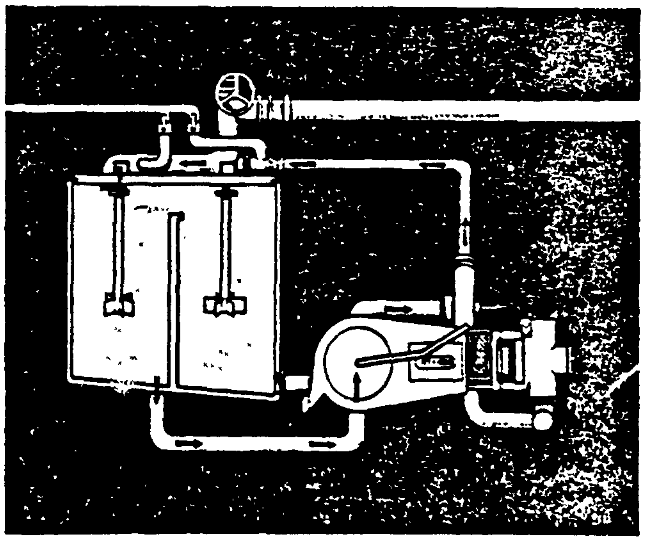
Halliburton Modular Recirculating Cement Mixer (RCM™) System

Halliburton's RCM™ system offers a unique combination of capabilities that makes accurate mixing possible over a broad range of operating conditions. Advantages of the RCM system include the following:

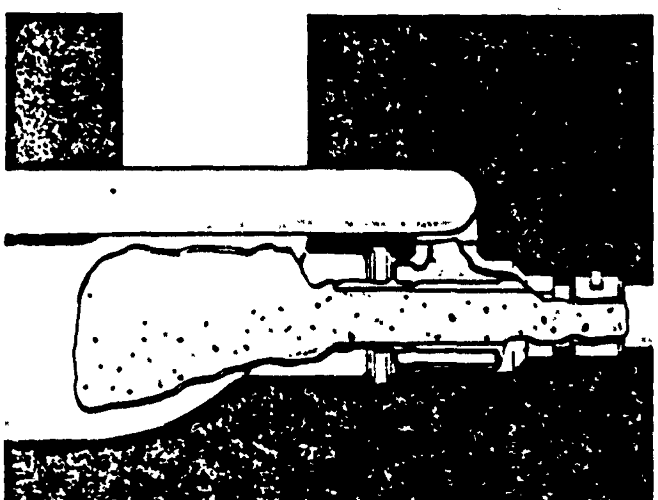
1. Slurries above 22 lb/gal may be accurately mixed.
2. Accurate slurry weight control makes the RCM ideal for critical liner, plug back, and squeeze jobs.
3. Initial lead and final slurries can be mixed to the desired weight.
4. Slurry operations can be closely controlled in order to provide desirable fluid loss, yield point, viscosity, etc.
5. Batches as small as 8 bbl may be mixed.
6. Slurry mixing rates as low as 0 bpm may be obtained.
7. Equipment may be arranged in a wide variety of ways.
8. The RCM system is built for operator convenience and safety, and operating efficiency.



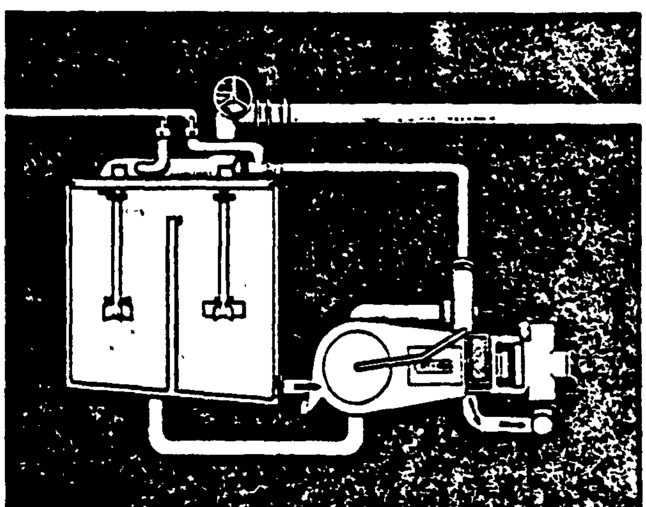
A. Components of the RCM.



C. Slurry is circulated, weighed, and adjusted.



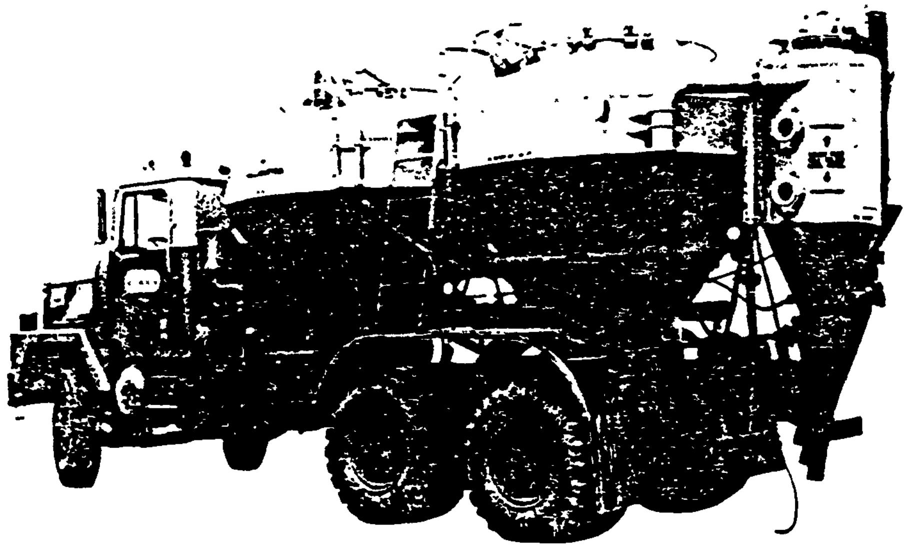
B. Recirculating mixer jet schematic.



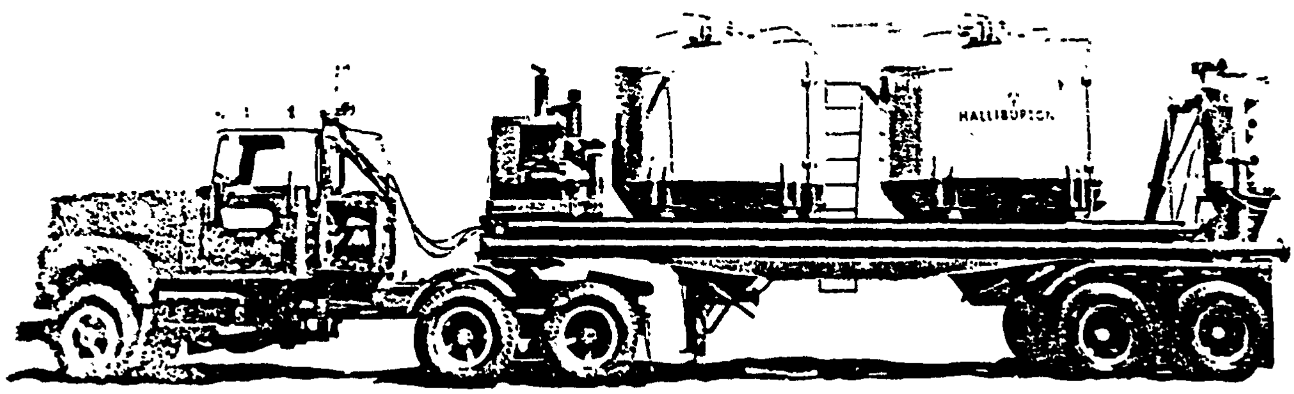
D. Slurry is pumped downhole.

HALLIBURTON
SERVICES

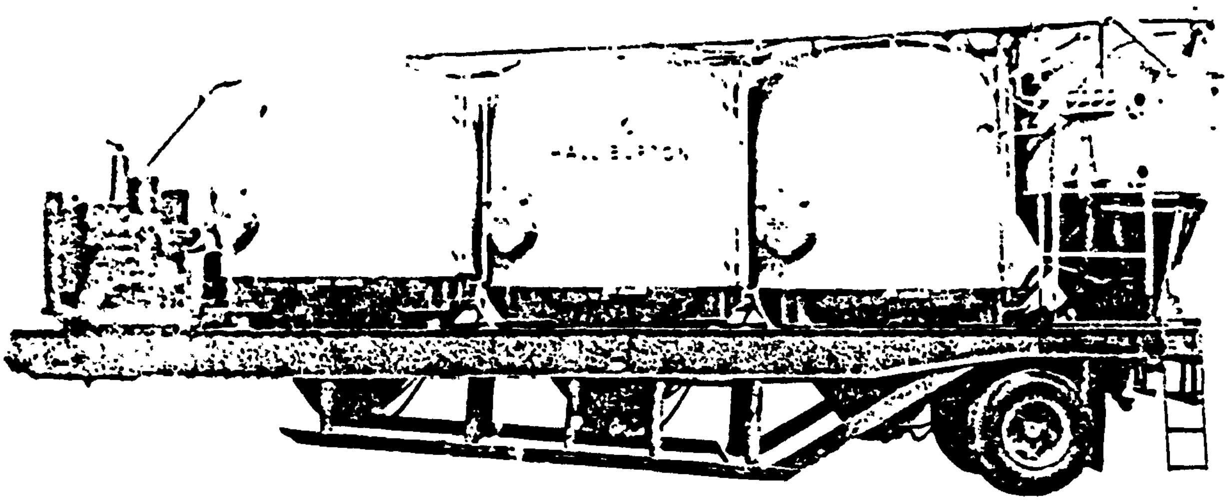
Bulk Cement Transports



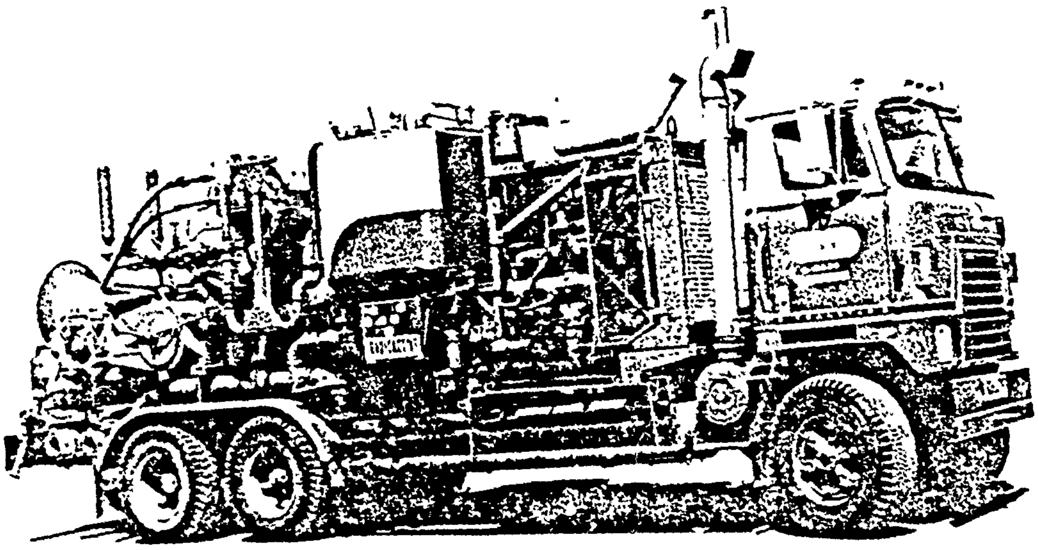
400 Cu Ft Body Load Pneumatic Bulk Transport



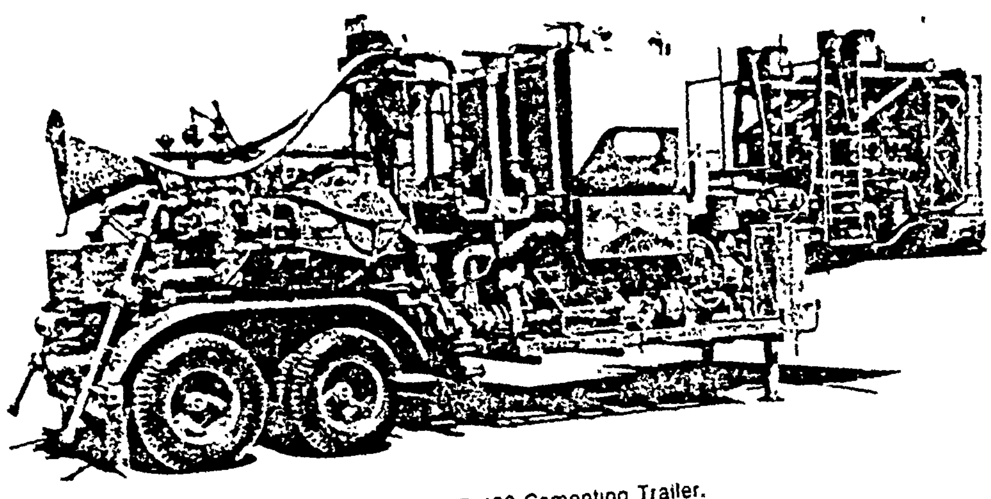
660 Cu Ft Pneumatic Bulk Cement Unit



1,410 Cu Ft Field Storage Unit



Standard Twin HT-400 Cementing Unit.



Standard Twin HT-400 Cementing Trailer.

CHARGE DATA SUMMARY

Charge Performance
Hollow Carrier Perforating Guns

Carrier Classification	Gun Size (in.)	Charge Designation	Temp/Press Rating (°F/psi)	Gun Phasing (°)	Explosive Load (gm.)	Debris	Third Edition API RP-43 Concrete Tests: Casing EHD	Third Edition API RP-43 Concrete Tests: Penetration (in.)	Third Edition API RP-43 Sec II Berea Tests: EHD	CFE	TTP	TCP	ECP
Hollow Carrier Casing	5	Big Hole	325/20,000	0/120	32.0	No	.67	11.10	.79	.93	12.10	10.97	10.16
	5	Big Hole XL	325/20,000	0/120	37.0	No	.82	8.73	.94	.81	4.74	3.61	2.92
	4	XLH-Jet	325/20,000	0/120	21.0	No	.92	5.01	.93	.76	4.72	3.59	2.71
	4	Big Hole	325/20,000	0/120	19.0	No	.71	10.20	.75	.77	7.14	6.01	4.60
	4	SSB® II	325/20,000	0/120	22.0	No	.50	23.64	.56	.85	14.86	13.73	11.63
	4	SSB®	325/20,000	0/120	22.0	No	.50	23.20	.56	.85	14.73	13.60	11.56
	4	Super Dyna-Jet® 18	325/20,000	0/120	18 0	No	.47	17.30	.49	.86	11.08	9.95	8 53
	3⅜	SSB®	325/20,000	0/120	11 0	No	34	15.36	.39	.80	10.60	9.47	7.61
	3⅜	Super Dyna-Jet® Plus	325/20,000	0/120	15.0	No	.44	11.63	.53	.77	8.15	7.02	5.42
	3⅛	Big Hole	325/20,000	0/120	10.0	No	.61	7.54	.62	.76	5.60	4.47	3.39
	3⅛	SSB®	325/20,000	0/120	11.0	No	.34	15.36	.39	.80	10.60	9.47	7.61
	3⅛	SSB® II	325/20,000	0/120	12.0	No	.38	19.36	.41	.83	11.10	9.98	8.27
	3⅛	Super Dyna-Jet® Plus	325/20,000	0/120	8.0	No	.41	9.25	.46	.72	6.18	5.50	3.60
Hollow Carrier Through Tubing	2¾	Sidewinder® SSB®	325/20,000	0/180	11 0	No	38	16 24	.37	75	10.55	9.42	7.10
	2	Sidewinder® SSB® II	325/20,000	0/180	6 5	No	32	10.37	36	79	8.15	7.02	5.53
	1 9/16	Sidewinder® SSB® II	325/20,000	0/180	3 0	No	.26	9 88	.29	.81	5 68	4.55	3.70
	1½	Sidewinder® SSB®	325/20,000	0/180	3 0	No	.25	8 12	.29	.81	5.48	4 35	3.52
	1⅜	Sidewinder®	325/20,000	0/180	2.5	No	—	—	.27	—	3.05	—	—

Charge Performance
Tubing Punchers

Carrier Classification	Gun Size (in.)	Charge Designation	Temp/Press Rating (°F/psi)	Gun Phasing (°)	Explosive Load (gm.)	Debris	EHD (in.)	Maximum Penetration Steel (in.)
Tubing Puncher	1⅜	Standard	325/20,000	0	2.5	No	.20	.25
	1½	Standard	325/20,000	0	2.0	No	.43	.52
	1 9/16	Standard	325/20,000	0	2.5	No	.43	.52
	1 9/16	PH II	325/20,000	0	1.5	No	.29	.61
	2	Standard	325/20,000	0	6 0	No	.30	.68

CHARGE DATA SUMMARY

Expendable/Retrievable Guns

							Third Edition API RP-43 Concrete Tests		Third Edition API RP-43 Sec II Berea Tests				
Carrier Classification	Gun Size (in.)	Charge Designation	Temp/Press Rating (°F/psi)	Gun Phasing (°)	Explosive Load (gm.)	Debris	Casing EHD	Penetration (in.)	EHD	CFE	TTP	TCP	ECP
Expendable Retrievable	3¼,4	Hornet Jet	300/12,000	0/180	19.0	Yes	.40	9.28	.51	.73	8.19	7.06	5.13
	2⅛	Clean Jet-Glass	300/7,500	0/180	22.0	No	.41	8.54	.49	.86	7.11	5.99	5.15
	2⅛	Ceramic-DF	300/15,000	0/180	20.0	No	.38	8.32	.51	.98	7.60	6.47	6.36
	2⅛	Ceramic-DF Clean Jet	300/12,000	0/180	20.0	No	.38	8.32	.51	.98	7.60	6.47	6.36
	1¹¹/₁₆	Dyna-Mite	300/13,000	0/180	13.0	Yes	.33	7.38	.40	.88	6.32	5.19	4.55
	1¹¹/₁₆	Ceramic-DF Clean Jet	300/20,000	0/180	13.0	No	.34	5.31	.38	.92	5.45	4.32	3.96
	1¹¹/₁₆	Ceramic-DF	300/20,000	0/180	13.0	No	.34	5.31	.38	.92	5.45	4.32	3.96
	1¹¹/₁₆	Clean Jet-Glass	300/7,500	0/180	13.0	No	.30	6.76	.27	.92	5.70	4.58	4.21
	1⅜	Dyna-Mite	300/14,000	0/180	6.0	Yes	—	—	.31	—	4.80	—	—
Expendable	2¹/₁₆	Link-Jet®	300/11,000	0/90	22.0	Yes	.45	9.17	.50	.92	7.82	6.69	6.13
	1¹¹/₁₆	Link-Jet®	300/13,000	0/90	13.0	Yes	.33	7.38	.40	.88	6.32	5.19	4.55
	1¹¹/₁₆	Swing-Jet®	300/12,000	0/180	19.0	Yes	.40	9.28	.51	.73	8.19	7.06	5.13

EXPLOSIVE SAFETY

Perforating involves extensive use of explosives. To insure that the handling of explosives in the field is a safe operation, every possible precaution is considered in the design, manufacture, and use of our equipment.

Field personnel are given thorough initial training in the use of explosives. This is followed by periodic instructional sessions in which basic practices are reviewed and new developments are introduced. Strict adherence to company safety guidelines is strongly emphasized.

Good communications in the use of explosives at the well site are of utmost importance. Rig personnel are provided with the information necessary for their assistance in achieving a safe and successful operation. To insure efficient communication among crew members, our personnel follow standard, well-established communications procedures.

Other safety precautions are employed to eliminate the possibility of accidental firing by stray current or static electricity. These include the use of grounding cables to connect the truck, wellhead, rig, catwalk, pipe racks, and other metal structures that the wireline cable or gun may contact during the operation. Radio transmissions are not permitted during perforating. In addition, perforating operations are not allowed during electrical, thunder, or dust storms.

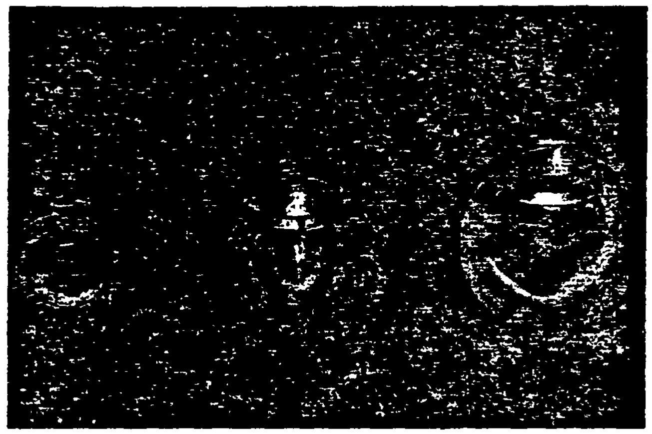
Our perforating equipment utilizes a multi-position switch containing back-to-back rectifiers; these insure that no current is supplied to the gun unless the switch is in the perforating position. Also incorporated are a key-controlled safety switch and a firing control requiring the simultaneous activation of two handles. These features eliminate any chance of accidental firing before total readiness is achieved.

Explosives are transported in strict compliance with Department of Transportation regulations as well as those set forth by state, county, and local governments. Vehicles are equipped with proper accessories for transporting explosives and are continually inspected and maintained for maximum safety.

Proper storage includes maintaining environmental conditions within required ranges and rotating the explosive stock. Additionally, guns are loaded only as they are needed. These precautions insure that fresh explosives are always used and that they will operate efficiently. All explosives are stored in conformance with regulations set forth by local and state agencies and the U.S. Treasury Department's Alcohol, Tobacco, and Firearms Division.

Welex

HOLLOW CARRIER CASING GUN



Hollow Carrier Casing Guns are used to perforate large diameter casing. These guns are both retrievable and reusable.

The heavy steel wall of the carrier absorbs the major portion of the shock from the charge detonation, thereby protecting the casing and cement from damage. Charge debris is removed from the well by the Hollow Carrier, thus preventing plugging of chokes, valves, and flow lines.

Charges are protected from wellbore fluids allowing for maximum operating pressures and temperatures. The large diameter of the Hollow Carrier permits a wider selection of charges. This allows for optimal use of charge designs.

The Big Hole and the XLH (Extra Large Hole) charges are designed to produce maximum entrance hole diameter. The Super Dyna-Jet®*, SSB®*, and SSB® II charges give maximum penetration.

The Hollow Carrier Casing Guns provide a rugged charge alignment system which permits spudding through light bridges in the wellbore. The Mark I Burrless, Jet-Vac®, and Gamma Perforating Systems can be utilized with most of these guns.

Diameter of Gun (in.)	**3⅛**	**3⅝**	**4**	**5**
Recommended Minimum Pipe I.D. (in.)	3.500	4.000	4.600	5.900
Recommended Minimum Passage (in.)	N/A	N/A	N/A	N/A
Maximum Pressure Rating (psi)*	20,000	20,000	20,000	20,000
Maximum Temperature Rating (°F)*	325	325	325	325
Carrier Interval Lengths (ft.)	3, 7, 11	3, 7, 11	3, 7, 11	3, 7, 11
Shots Per Foot	1 to 4	1 to 4	1 to 4	1 to 4
Maximum Shots Per Trip	120	120	120	120
Centralized	As Required	As Required	As Required	As Required
Decentralized	As Required	As Required	As Required	As Required
Available Phasing (°)	0, 120, 180	0, 120, 180	0, 120, 180	0, 120, 180
Debris	None	None	None	None
Selective Fire Available	Yes	Yes	Yes	Yes

*Higher ratings available. See HOT™.

*A registered mark of Jet Research Center, Inc. a Halliburton Company.

Hughes Waterwell Bits...Right Bit...Right Size For Any Job

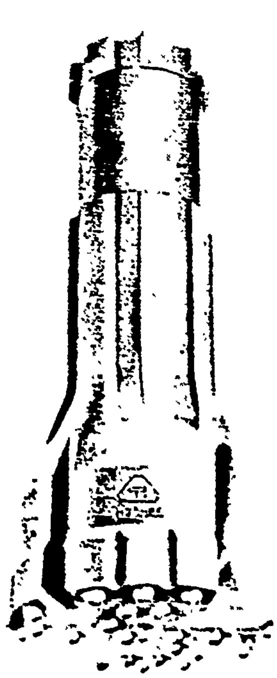
You can put your wells down faster—and surer—when you use Hughes bits. This is possible because a significant part of every dollar you spend for Hughes rock bits goes directly into research to improve the products. As a part of the overall program, performance facts are collected and tabulated, checked and evaluated to continually improve our bits . . . a program that assures you of superior performance from every Hughes bit you run whether it's a Blue Demon, Tri-Cone or Ram-Blast. Through this never ending research Hughes has developed the right bit in the right size for every type of drilling.

Hughes BLUE DEMON replaceable blade bits are effective and efficient all-purpose blade-type bits. BLUE DEMON bit bodies come in four sizes; the MP-200 for blades from 1⅞" through 3¼", the DB-400 from 3" through 4¼", the AC-600 from 3⅞" through 6¾" and the SH-800 from 5⅝" through 13". All of these bodies use low cost expendable blades which are designed to be completely worn out and thrown away. BLUE DEMON blades are available in either Rock Cutter or Insert types to meet every drilling need.

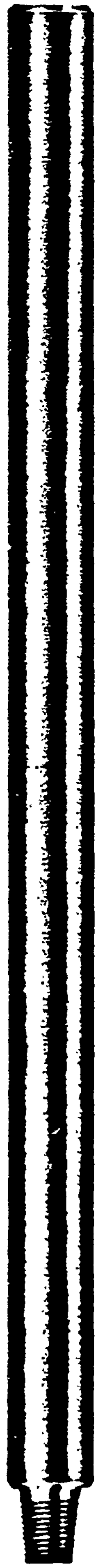
Hughes "Tri-Cone" rolling cutter rock bits are for drilling a variety of formations. They are engineered for fast, economical drilling using water or mud.

There is a Hughes "Tri-Cone" bit to drill every formation . . . soft to medium hard, medium hard, and hard abrasive formations. Hughes "Tri-Cone" bits come in all popular sizes.

Hughes RAM-BLAST percussion bits are for use in any rock drilled with air-operated percussion drilling tools. RAM-BLAST bits are designed for continuous use with no stops for sharpening. Extra tungsten carbide located at the gage of the bit resists wear and keeps the bit free cutting. Compacts spread over the bit face work the entire bottom of the hole at each blow of the hammer. RAM-BLAST bits are available in 6", 6⅛", 6½", 7" and 9" sizes.



For additional information and literature call your Hughes Industrial Products Dealer.



DRILL COLLARS

Drill collars are heavy drill string members used as weight which forces the bit to penetrate the formation being drilled.

All drill collars are full length heat treated to obtain the best physical properties and to provide a combination of hardness, strength and ductility.

The collars are made from selected bars of chromium molybdenum alloy steel (AISI 4145 H for smaller sizes and AISI 4145 H modified analysis for larger sizes).

Drill collars are bored by trepanning to insure close tolerance of bore alignment. (All drill collars are drifted to API specifications and we are authorized to use the API monogram.)

GENERAL NOTES ON DRILCO INDUSTRIAL DRILL COLLARS

1. SURFACE FINISH

   (a) "As Rolled"—This is the regular mill finish on the bar as received from the mill. It is satisfactory for all nominal drill collar requirements. Mill finish bars meet API specifications on O.D. tolerances. "As Rolled" drill collars offer a saving to the user with no effect on performance.

   (b) "Machined"—To obtain a machined finish drill collar, ⅛" to ¼" of steel is machined off the O.D. of the raw stock. Because of improved mill rolling practices, expense of machining, and loss of material, "As Rolled" collars are generally recommended.

2. LENGTH

   Drilco Industrial standard water well drill collars are available in 10, 15, 20, and 30 foot lengths, or as specified.

3. BORE

   Standard bores are noted in the drill collar chart. Special bores for particular projects as well as step bores for increased joint strength and/or improved hydraulic conditions are available at extra cost.

4. CONNECTIONS

   Standard connections are precision machined to API specifications. Additional connections such as: DI-Series, Failing Exploration, Mayhew, Joy Full Hole, Winter Weiss, and others are available on request. All connections are protected by a phosphate surface coating (Kemplate) to minimize galling during makeup. Pressed steel or plastic thread protectors are furnished on most popular size drill collar joints.

For patent information see Table of Contents

5. SPECIAL FEATURES

The following special features are also available on request:

(a) API Relief Groove on Pin or Box

(b) Patented Drilco Boreback® Box

(c) Cold Rolled Thread Roots

(d) Surface Finish — "As Rolled" or Machined

(e) Other special features such as elevator and slip recesses, wrench squares, flats, slots or special breakout configurations. Drawings with dimensions must be supplied for all breakout configurations.

(f) The drill rig make and model with a description of the use of the drill collars will help assure satisfactory field performance.

6. WHEN ORDERING PLEASE SPECIFY:

(a) Outside diameter — Bore — Length

(b) Size and type of tool joint — each end of collar — and Special joint features.

(c) Step Bore or Straight Bore

Caution: Safety precautions should be taken when handling drill collars. If a lift-type thread protector is used, do not exceed the maximum lifting load capacity for a given size and type. (Check load rating page 26). When lifting heavy collars vertically, we recommend the use of heavy-duty lift plugs or lift subs, and be sure they are shouldered up.

STANDARD SIZES, BORES AND CONNECTIONS FOR DRILCO INDUSTRIAL DRILL COLLARS

Standard Lengths Of 10, 15, 20, 25 and 30 Feet Are Available Or Special Lengths As Specified

Drill Collar Number* or Size & Style	Outside Diameter Inches Minimum	Bore Inches Tolerance + 1/16 − 0	Bending Strength Ratio ***	Approximate Weight of Drill Collars Lbs/Ft
NC 26-35 (2⅜ IF)	3½	1½	2.42:1	26.7
NC 31-41 (2⅞ IF)	4⅛	2	2.43:1	34.7
NC 35-47	4¾	2	2.58:1	49.6
NC 38-50 (3½ IF)	5	2¼	2.38:1	53.3
NC 44-60	6	2¼	2.49:1	82.6
NC 44-60	6	2$^{13}/_{16}$	2.84:1	75.9
NC 44-62	6¼	2¼	2.91:1	90.5
NC 46-62 (4 IF)	6¼	2$^{13}/_{16}$	2.63:1	83.8
NC 46-65 (4 IF)	6½	2¼	2.76:1	99.5
NC 46-65 (4 IF)	6½	2$^{13}/_{16}$	3.05:1	92.8
NC 46-67 (4 IF)	6¾	2¼	3.18:1	108
NC 50-70 (4½ IF)	7	2¼	2.54:1	117
NC 50-70 (4½ IF)	7	2$^{13}/_{16}$	2.73:1	111
NC 50-72 (4½ IF)	7¼	2$^{13}/_{16}$	3.12:1	120
NC 56-77	7¾	2$^{13}/_{16}$	2.70:1	140
NC 56-80	8	2$^{13}/_{16}$	3.02:1	151
6⅝ Reg	8¼	2$^{13}/_{16}$	2.93:1	162
NC 61-90	9	2$^{13}/_{16}$	3.17:1	196
7⅝ Reg	9½	3	2.81:1	217
NC 70-97	9¾	3	2.57:1	230
NC 70-100	10	3	2.81:1	243
8⅝ Reg**	11	3	2.78:1	299

*The Drill Collar Number Consists of NC (Number Connection). A Two Digit Number Indicating the Pitch Diameter of The Connection in Units & Tenths, A Hyphen, A 2 or 3 Digit Number Consisting of The Outside Diameter In Units and Tenths The Size and Style in Parentheses Indicate Interchangeable Connections.

**Low Torque Face.

***Ratio of Box to Pin Section Modulus See API RP7G For Explanation

For patent information see Table of Contents

COMPARATIVE MECHANICAL PROPERTIES*

PLAIN END TUBING

Class	Yield PSI	Tensile PSI
API N-80	80,000	135,000
API K-55	55,000	95,000
ASTM A-53	35,000	60,000

API UPSET DRILL PIPE

Grade	Yield PSI	Tensile PSI
G	105,000	180,000
E	75,000	130,000
D	55,000	95,000

**Refer to API RP7G for additional "Recommended Practice For Drill Stem Design and Operating Limits".*

NOTE: When drill pipe is racked or transported in the field, Drilco Industrial recommends that pin and box protectors be used to prevent damage to the threaded connections.

Other popular connections, tubing dimensions, and/or special combinations are available to accommodate requirements.

When ordering or requesting a quotation please specify:

(1) Upset Drill Pipe or Flush Drill Stem

(2) Class or Grade of Tubing

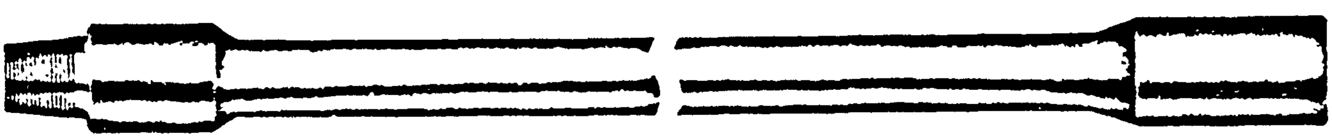
(3) Tubing dimensions (outside diameter, wall thickness, weight per foot)

(4) Tool Joint Connections

(5) Drill Pipe or Drill Stem Length

(6) Special Features

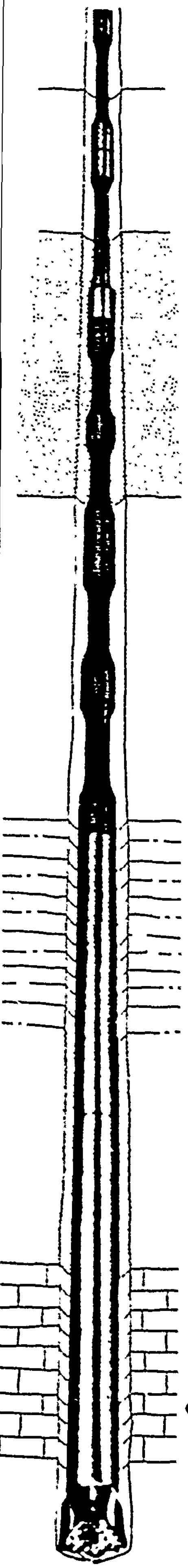
UPSET DRILL PIPE



UPSET DRILL PIPE SIZES

TOOL JOINT					TUBING				LENGTHS APPROX. WEIGHT PER PC.	
Connection	OD Ins	L Min L_{PB} & L_B	ID Ins	Lbs/In	OD Ins	Wall	Upset	Lbs/Ft	Range 1	Range 2
2⅜ IF (NC-26)	3⅜	15	1¾	1.85	2⅜	.280	EUE	6.65	162	225
2⅞ IF (NC-31)	4⅛	15½	2⅛	2.78	2⅞	.362	EUE	10.40	253	352
3½ IF (NC-38)	4¾	16½	2 11/16	3.41	3½	.368	EUE	13.30	324	450
4½ FH	5¾	17	3	5.35	4½	.337	IUE	16.60	424	582
4 IF (NC-46)	6	17	3¼	5.62	4½	.337	IUE	16.60	430	587
4½ IF (NC-50)	6¼	17	3¾	5.56	4½	.337	EUE	16.60	428	585
5 XH	6¼	17	3½	5.96	5	.362	IEUE	19.50	493	678
4½ IF (NC-50)	6½	17	3¾	6.26	5	.362	IEUE	19.50	498	683
NC-56	7	18	3¾	7.76	5½	.361	IEUE	21.90	578	786
5½ IF	7½	18	4 13/16	7.35	5½	.361	EUE	20.00	532	722
6⅝ FH	8	19	5	8.67	6⅝	.330	IEUE	25.20	667	906
6⅝ IF	8½	19	5 29/32	8.30	6⅝	.352	EUE	24 00	636	864

For patent information see Table of Contents



HEVI-WATE* DRILL PIPE

Drilco Industrial's Hevi-Wate drill pipe is an intermediate weight drill string member. It consists of a heavy wall tube attached to special extra length tool joints. It has drill pipe dimensions for ease of handling. The integral center wear pad protects the O.D. of the tube from abrasive wear. The extra length tool joint end sections allow ample space for re-cutting the connections and reduces the rate of wear on the outside diameter.

"Hevi-Wate drill pipe" is used in the "Transition Zone of Destruction" to maintain a balanced change of section between the rigid drill collars and the limber drill pipe. The length of the destructive zone is variable, usually occurring in the lower 4 to 6 connecting limber joints. Fatigue in these lower joints due to cyclic torsional and resonance whipping, bounce and drill collar shifting is minimized with the use of Drilco Industrial's Hevi-Wate drill pipe.

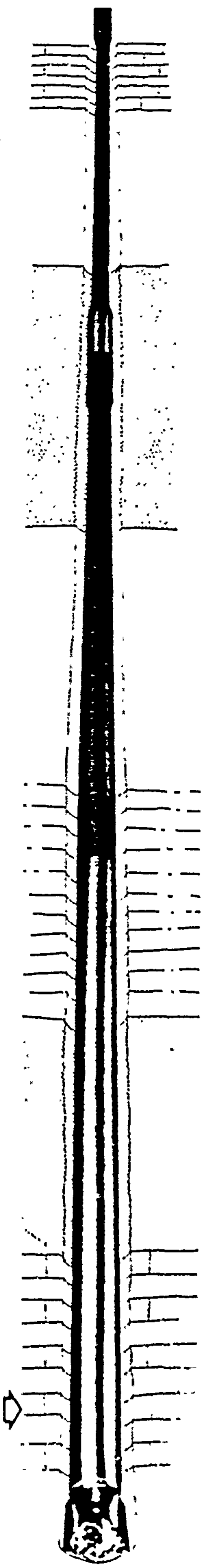
Hevi-Wate drill pipe, run in compression for bit weight, can reduce the hook load of the drilling string making it ideal for smaller rigs drilling deeper holes. In shallow drilling areas where regular drill pipe is run in compression, the more rigid Hevi-Wate drill pipe will allow more bit weight to be run with less likelihood of fatigue damage. It can safely be used for bit weight in vertical hole sizes up to 4 inches larger than the tool joint size. The longer end sections of the Hevi-Wate drill pipe provide more bearing area to resist wear on the center of the tube and the joints.

The Hevi-Wate drill pipe requires only drill pipe elevators. No safety clamp is required and regular drill pipe slips are used. A long string of Hevi-Wate drill pipe will eliminate many of the problems associated with drill collars normally used on the smaller rigs.

TRANSITION DRILL COLLARS

Drilco Industrial's transition drill collar is an intermediate weight drill string member. It is used to gradually distribute the stiffness ratio over the maximum available length from large-diameter drill collars to upper limber drill string members. This graduated change in stiffness reduces fatigue failures in the "Zone of Destruction" due to abrupt change in section. Used in conjunction with "Hevi-Wate" and/or small drill collars, it provides a smooth, tapered drill string. It will significantly minimize failures through the transition zone.

A transition drill collar consists of full-size alloy steel bar machined on a taper. The bottom section is the same diameter as the connecting drill collar. The upper section complete with slip recess for ease of handling will match the O.D. of the connecting limber drill string member. All "DI" transition drill collars are made from AISI 4145H modified alloy bar full length quenched and tempered. The ends and tapered center section are machined to specifications.



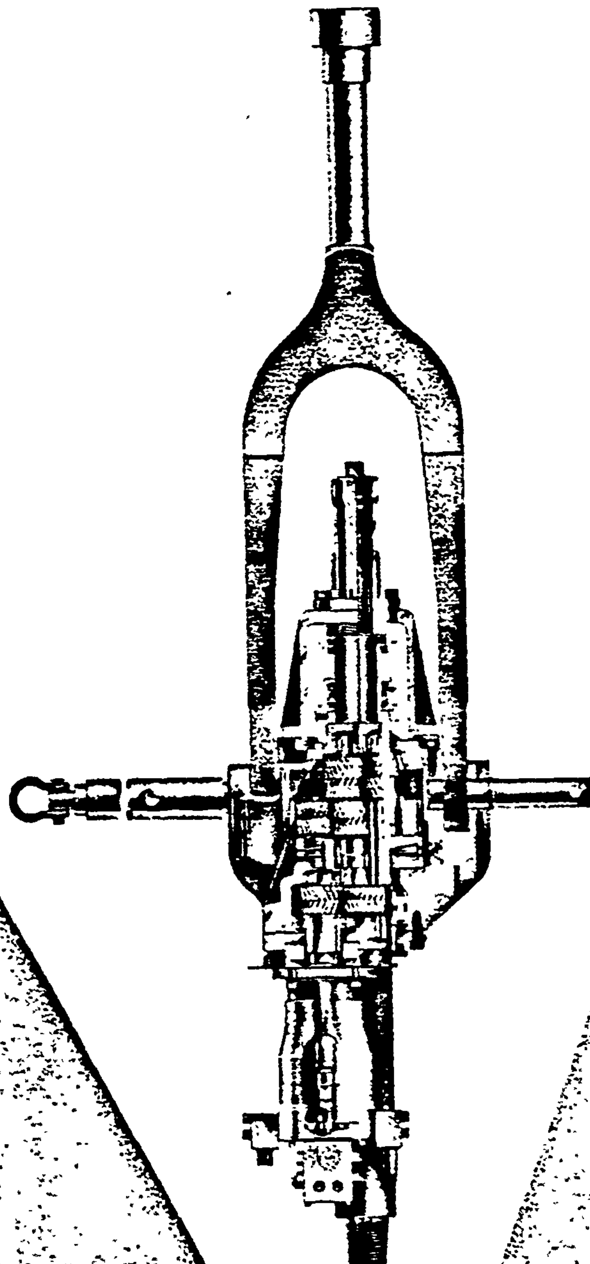
Hevi-Wate* Drill Pipe is used in the "Transition Zone of Destruction" to maintain a balanced change of section between the Rigid Drill Collars and the Limber Drill Pipe.

Drilco Industrial's Transition Drill Collar is also an Intermediate weight Drill String Member. It is used to gradually distribute the stiffness ratio over the maximum available length from Large Diameter Drill Collars to the upper Limber Drill String Members.

***Hevi-Wate is a Drilco Industrial Trademark**

For patent information see Table of Contents

INSTRUCTION MANUAL



BOWEN
85 TON
MODEL S-2.5
POWER SWIVELS
W/UNITIZED PACKING

BOWEN ®

Bowen Tools, Inc.

A BTC INDUSTRY

A-669

MANUAL No. 5/7025

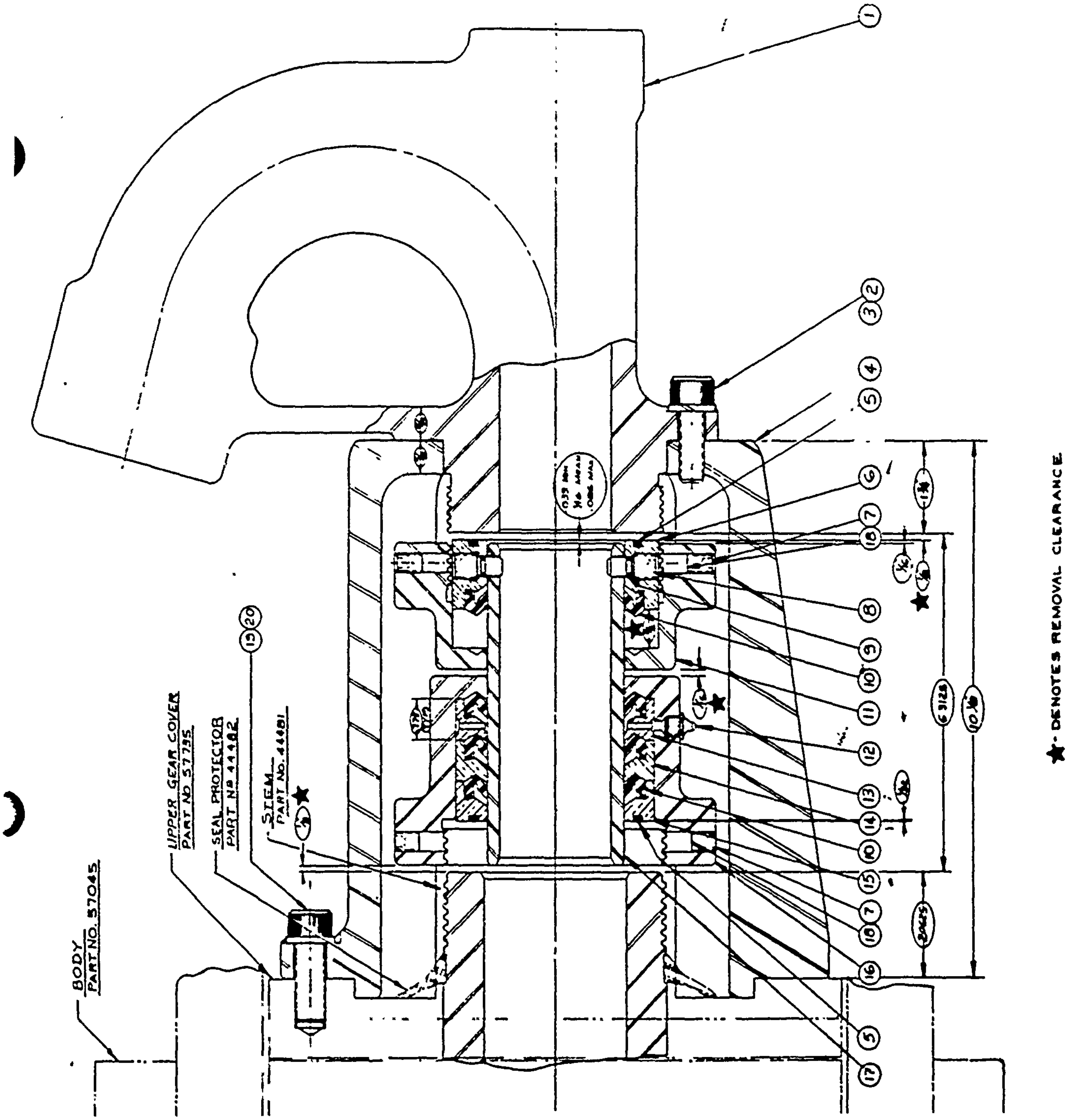


Fig. 3
BOWEN
S-2.5 Power Swivel Floating Washpipe Assembly

ITEM NO	PART NO	QTY.	DESCRIPTION	ITEM NO	PART NO.	QTY	DESCRIPTION
1	82090	1	Gooseneck	11	82093	1	Upper Packing Nut
2	22353	4	1/2 - 13 x 1-1/2" Lg. Soc Hd. Cap Scr.	12	27636	1	Packing Nut Grease Fitting
3	31827	4	1/2" Lockwasher	13	82096	1	Spacer and Lantern Ring
4	82091	1	Bonnet	14	72326	1	Plain Spacer Ring
5	6230-14	2	"O"-Ring	15	72324	1	Packing Bottom Ring
6	82097	1	Upper Packing Nut Ring	16	82092	1	Lower Packing Nut
7	23705	8	3/8 - 16 NC. x 1/2 Lg Socket Set Screw Flat Point	17	82094	1	Washpipe
				18	82102	8	Washpipe Packing Nut Scr. Retainer
8	82099	3	Washpipe Locking Pin	19	12019	4	5/8" - 11 x 1-1/2" Lg. Soc. Hd Cap Scr
9	568-010	3	"O"-Ring	20	31828	4	5/8" - Lockwasher
10	72327	1 Set	Packing				

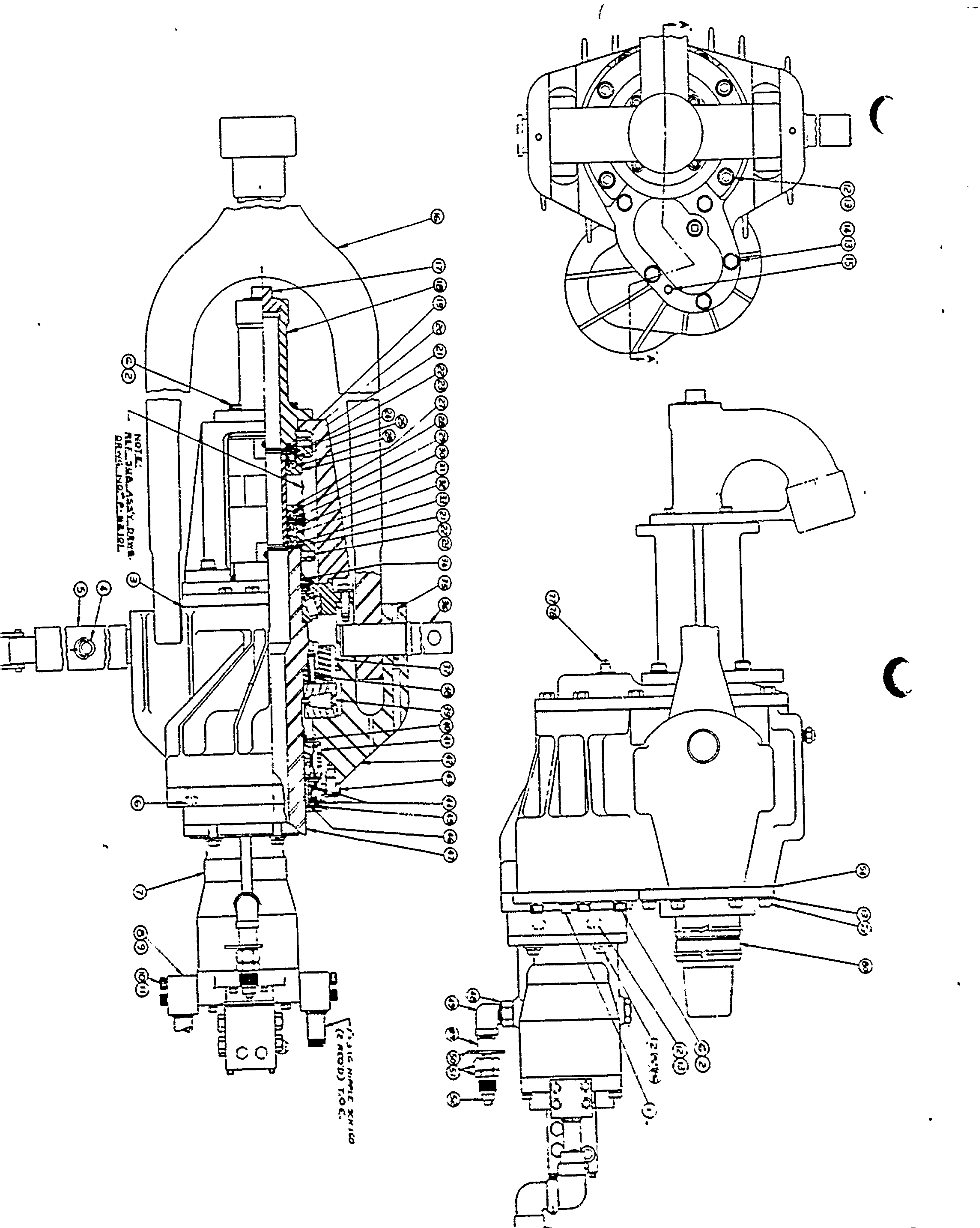
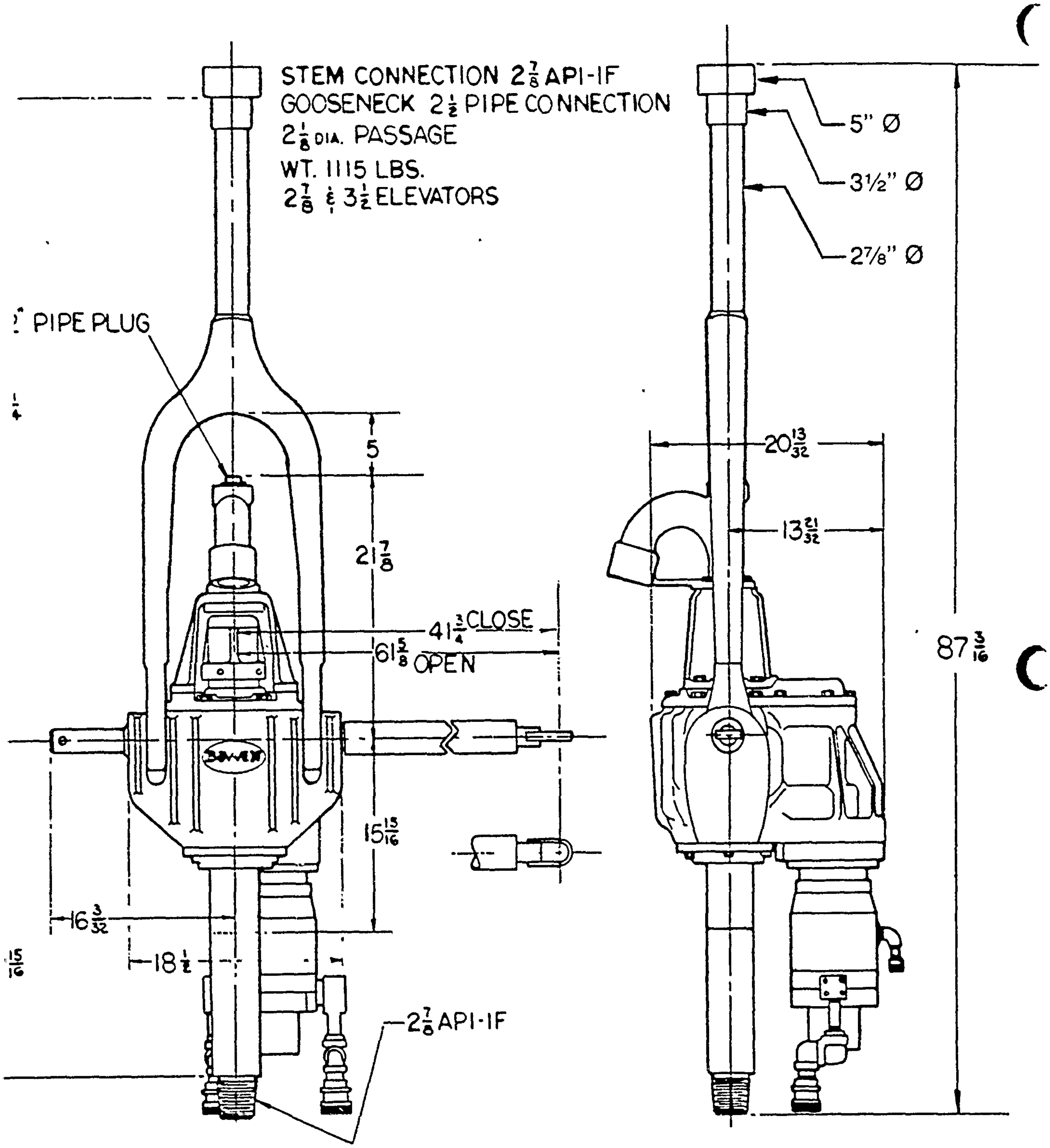
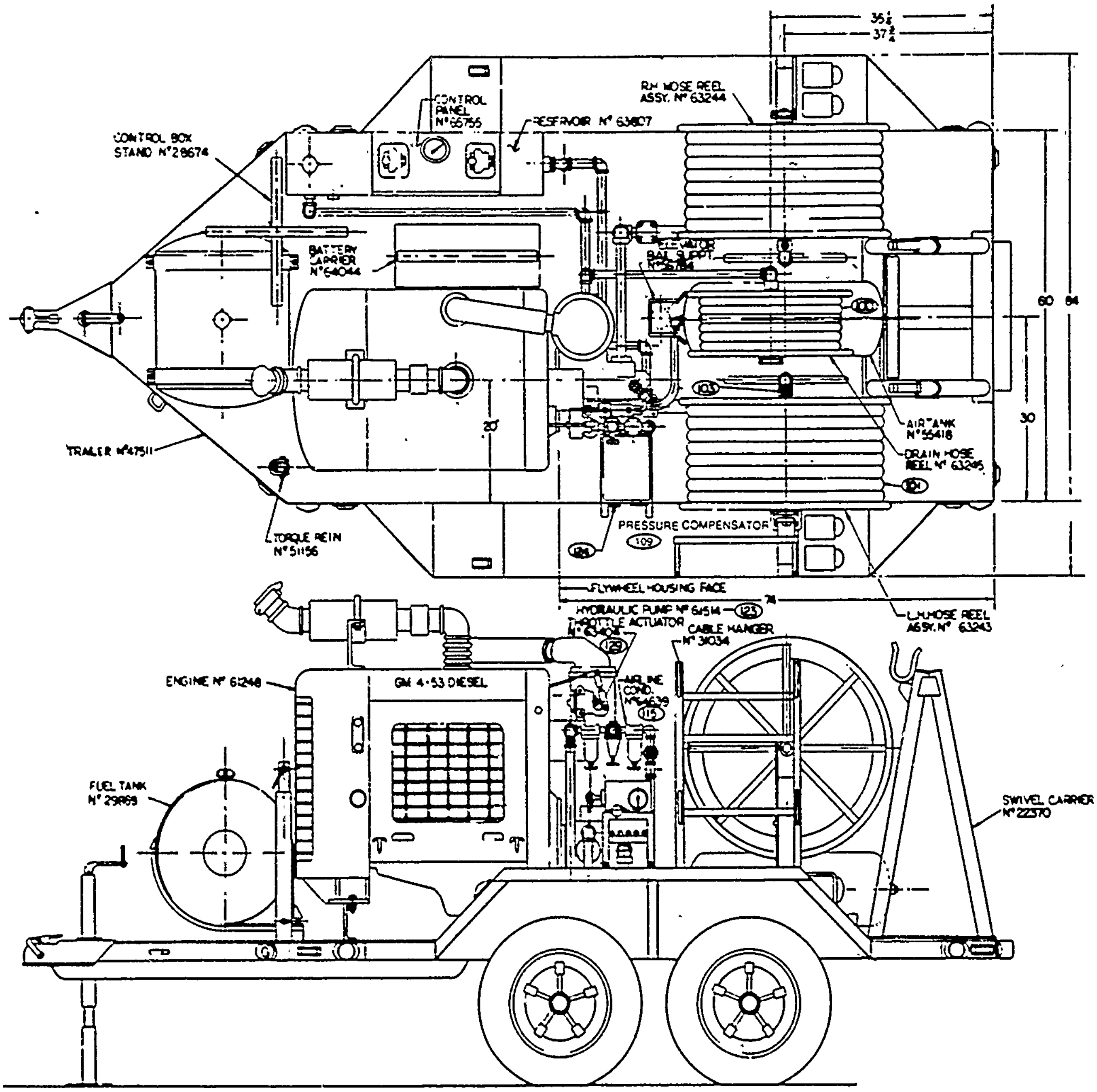


Fig. 4
BOWEN
S-2.5 Power Swivel Assembly Drawing

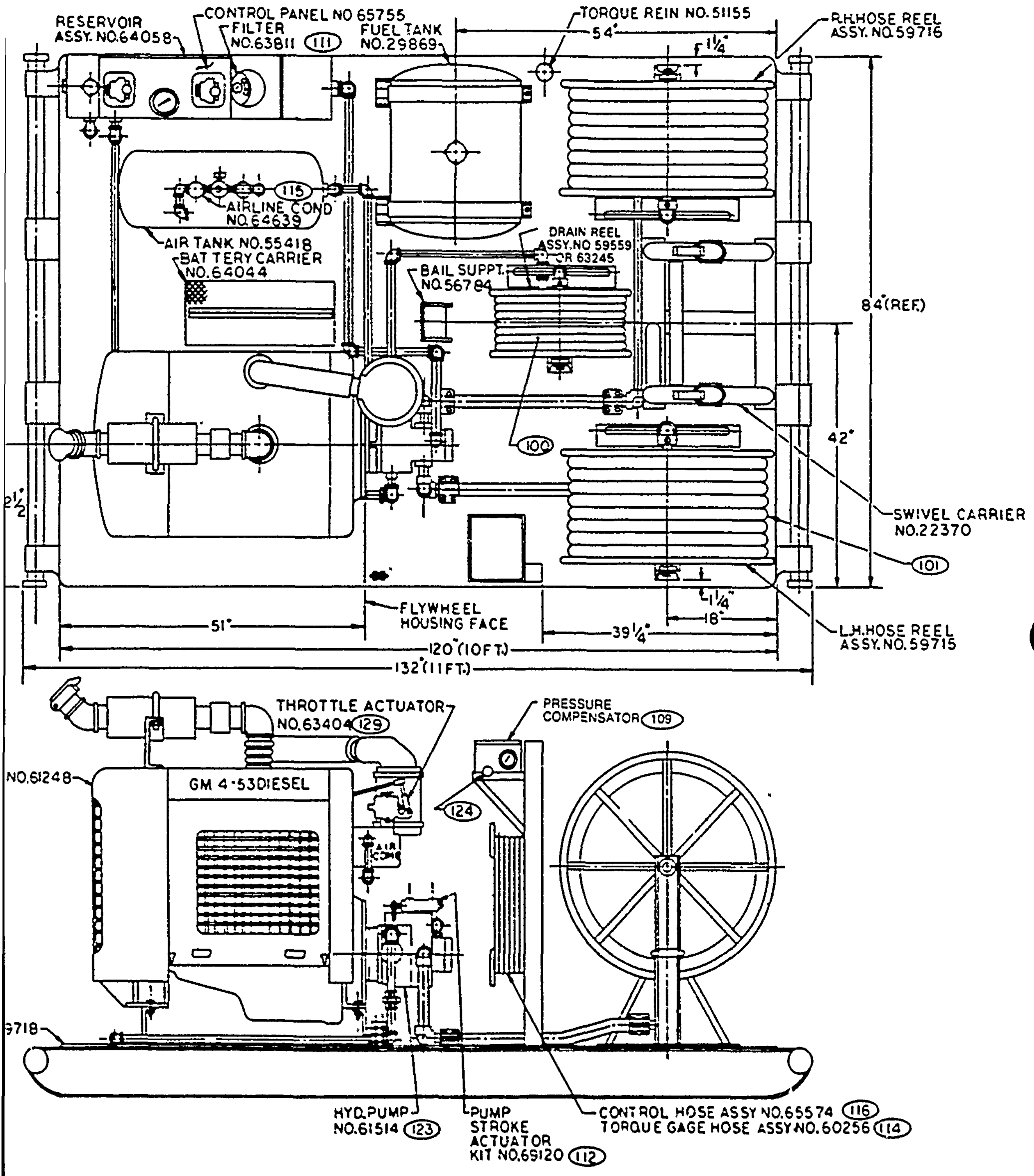


POWER SWIVEL S-2.5A&C



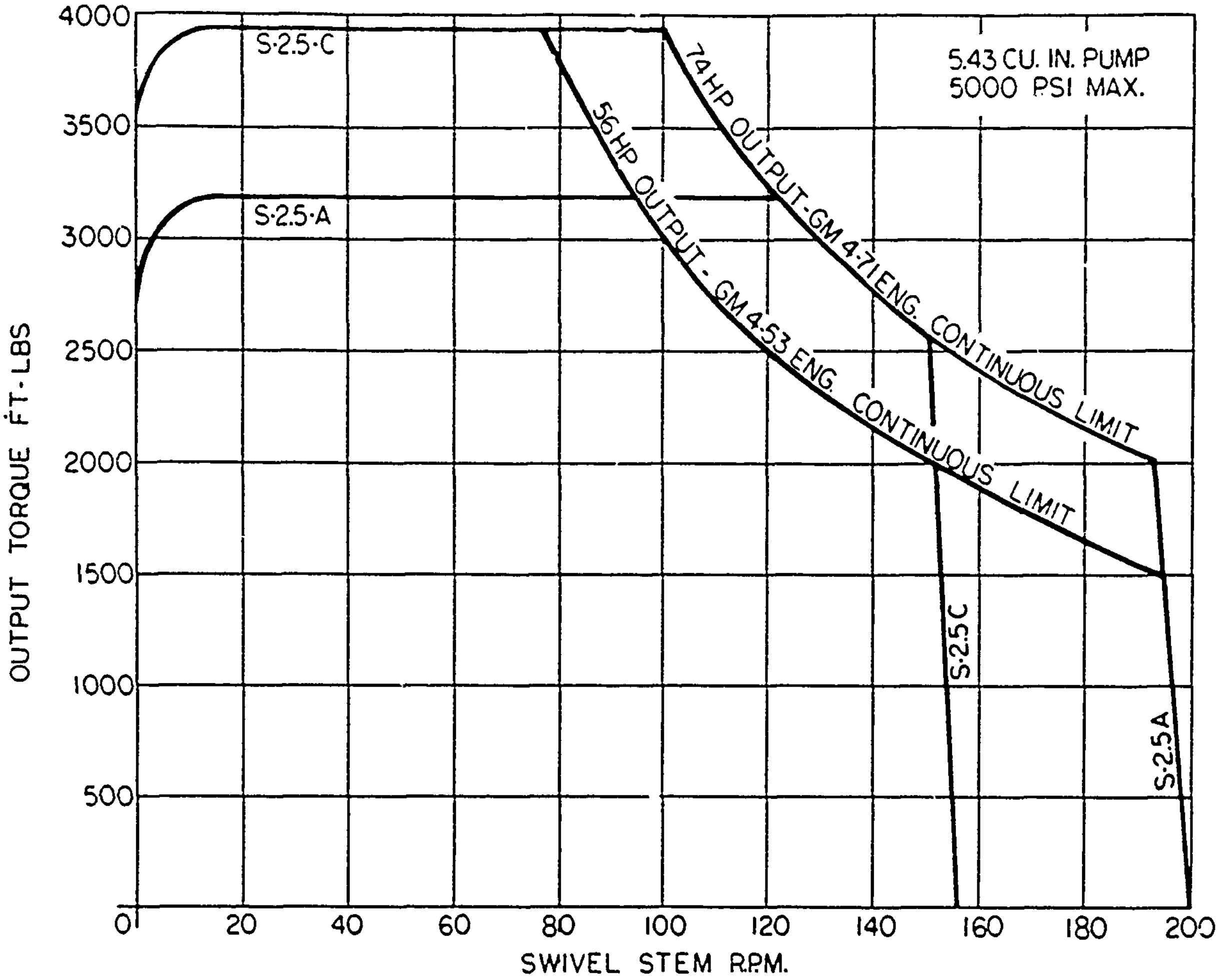
TRAILER MOUNTED PRIME MOVER

NOTE: FOR NUMBERED ITEMS SEE LISTING STARTING ON PAGE 25.

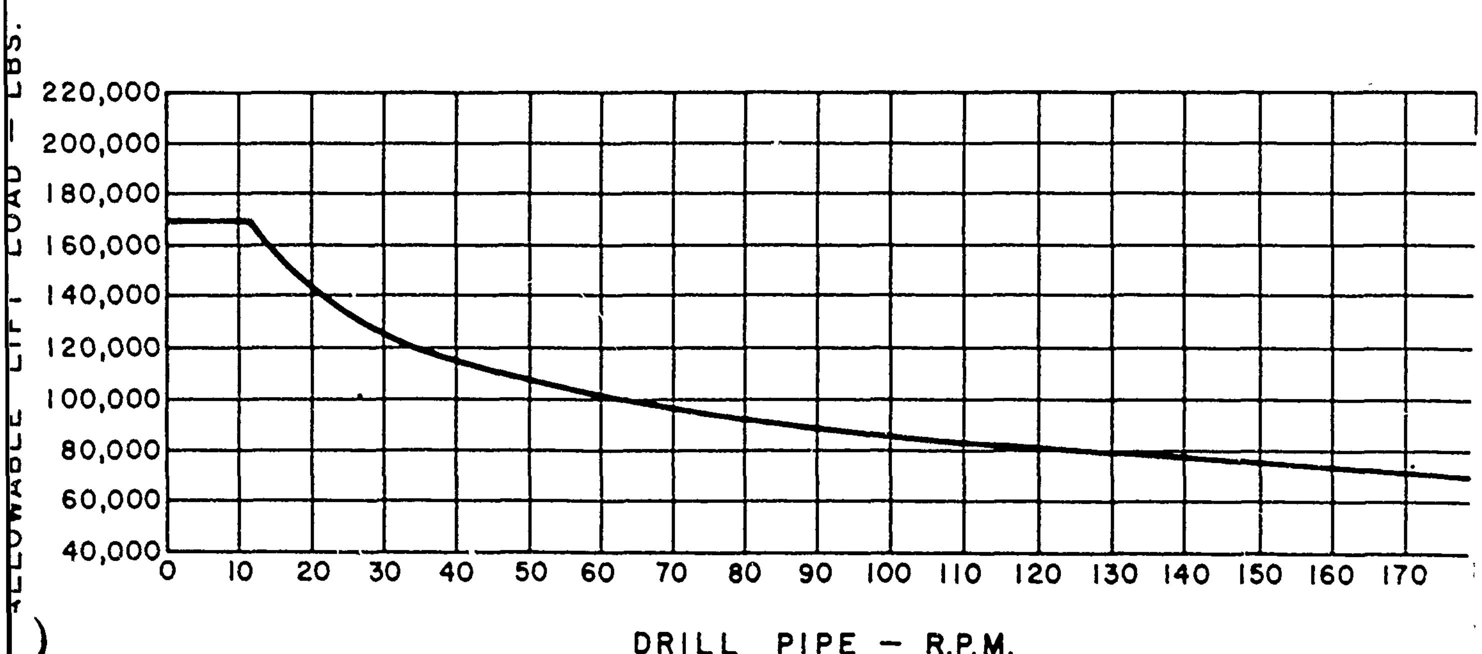


SKID MOUNTED PRIME MOVER

NOTE: FOR NUMBERED ITEMS SEE LISTING STARTING ON PAGE 25.



PERFORMANCE DATA – BOWEN S-2.5 A & C POWER SWIVEL



PERFORMANCE DATA – BOWEN S-2.5 A & C POWER SWIVEL